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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

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THE IGNEOUS ROCKS IN THE LIGHT OF HIGH-TEMPERATURE RESEARCH

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ACCORDING to the Newtonian mechanics an object attracts another object with a force that is inversely proportional to the square of its distance. Nowadays the relativists would have us regard the matter in a somewhat different light, but I think we might, even in these parlous times, postulate safely that an object attracts the human mind with a force that is, not inversely, but directly proportional to the square of its distance. There is an old rhyme that reads:

> Twinkle, twinkle, little star,
> How I wonder what you are.

It expresses a fundamental human attitude that begins in early childhood and never leaves us. So it comes about that one who would address a public gathering upon some aspect of the stars, the moon, the depths of the ocean, the inside of an atom or other remote and relatively inaccessible object may plunge into his subject without preamble and be assured of an interested audience. But one who would speak of the scientific aspects of seemingly more familiar things, such as the igneous rocks of this earth, will perhaps be well advised to assure himself that his audience knows just what these rocks are.

When I was a boy my comrades and I ranged a countryside whose woods and waters were a never-failing source of delight. We were town boys, and our excursions, be it confessed, were often of the nature of forays. Two types of countryside lay before us. The one of these, comparatively flat and featureless, was occupied by cultivated fields with an occasional patch of woods, usually hardwood bush. Here we robbed sap-buckets in spring, orchards and hickory groves in autumn. The other type of countryside was rugged and wild, locally covered with evergreen woods, but much of it bare and barren rock. We could rob such an area of little other than its spring flowers, but this we did and robbery it was, too, for the rarest and finest always grew in sections posted against trespass. In the height of summer and in the depth of winter we turned from these lawless courses into other pursuits even more delightful—swimming and skating.

Along the borders of the lake, in whose waters we spent the golden hours of many a summer day, it was apparent even to a small boy that the flat country, stripped of its soil, was made up of flat-lying layers of rock sloping gently and shelving gradually out into deep water. This was important, for in such spots the little tads of seven or eight splashed about in shallow water and learned their first strokes in safety. But big chaps of twelve or thirteen despised such spots. We sought the rugged countryside with its correspondingly rugged shores. Here

we could dive from a rock ledge into clear, green water fifteen or twenty feet deep, or again so deep that none of us could fetch bottom. The rock was of an altogether different kind. It was red in color, totally lacking in the regular flat layering, massive, solid, hard.

The contrasted structural and other characteristics of these two types of rock were impressed upon us in other ways. Both rocks were quarried and we loved to watch the quarrying operations. The layers of limestone, for we may now give the rocks their accepted local names, were parted readily by means of a crowbar and, with a minimum of labor, rectangular blocks were obtained to be used extensively in all the more substantial buildings of town and country. The massive, red granite was won with greater difficulty and was used in part for "trim" in the more pretentious structures, in part for monuments. The latter use depended upon the fact that it would take a fine polish, and on the polished surface one could see that it was made up of differently colored grains, some milky white, some red or pink, some glistening black. To this color-mottling the polished rock owed a large measure of its beauty.

The quarries were magnets to us not only during active operations but even after these were abandoned, because then they ordinarily filled with water. At quarry ponds we found our first swimming of early summer and again our first skating of early winter.

Thus in one way or another we were brought into rather intimate contact with the rocks of the area. It is very difficult to be sure just when and how a knowledge of the fundamental character of an object first comes, but I believe we spontaneously reached the conclusion that the layered limestone had been laid down in water as a mud or silt. That we reached, independently, any conclusion as to the nature of the granite is greatly to be doubted. It was probably only from explanations by our elders that we gained any concept of the granite, and it was not until I grew up and studied geology that I reached an adequate concept. I then learned that my boyhood haunts had lain where an ancient sea had washed an ancient shore consisting largely of granite, and had deposited upon the granite layer upon layer of mud made up of the comminuted shells of marine organisms, which mud, upon burial under a great thickness of similar material, had become a limestone. I learned that through a study of the better-preserved shells in the limestone a picture was to be had of the life that throve in that ancient sea and that, if one examined the shells found in the successively higher horizons of the overlying stratified rocks as they outcropped on the other side of the lake, a knowledge was obtained of the development of life in ancient seas through the long ages necessary to the accumulation of the great thickness of sands and silts represented in these layered rocks. But it was not this remarkable document that I found of greatest interest, for I learned that the granite was an igneous rock, a rock that had cooled slowly from the molten condition under a thick covering of overlying rocks since removed by the wear of the elements; that the variously colored grains I had seen in it were crystals of individual mineral compounds; that these crystals, when examined in a special type of light, called polarized light, gave most interesting effects, each in its own way; and that by measuring these effects the different mineral compounds could be identified. These and other features of the igneous rocks turned my interest towards them. I have been studying them ever since.

In the interior plains of this continent a boy would not ordinarily become acquainted with igneous rocks in the raw

and in their original setting. He might, however, have the opportunity of seeing igneous rock in use as an ornamental stone, forming columns, arches and the like in the portals of public buildings. Even in a small community without imposing edifices there is always the graveyard. There each seeks, in death as in life, to outdo his neighbor in splendor, and among the monuments to this folly there are usually some fine examples of igneous rocks. They may be of any hue from nearly white through various shades of red, green and gray to black itself and the observant individual might make out on polished surfaces that the dominant tone depends upon the dominance of one or another of the crystalline mineral grains of which the rocks are composed.

I have dwelt thus upon pleasant reminiscences and have descended therefrom to the surroundings of the graveyard with the purpose of emphasizing some of the many ways in which the igneous rocks and other rocks may become a part of the ordinary concerns of the average individual, especially of one living on this continent. Dwellers of other lands may have the igneous rocks (fire-rocks) brought into their lives in much more emphatic manner, that is, as a product of volcanoes.

Igneous Activity

Probably no more impressive spectacle is ever viewed by human eyes than that of a volcano in eruption. Close spectators of the more violent phases of vulcanicity seldom survive to relate their experiences. In the eruption of Pelée in 1902 the town of St. Pierre was wiped out by hot blasts of gas that carried incandescent rock powder. One man, who was lodged in the town's most substantial building, the prison dungeon, survived his 30,000 more respectable fellow-townsmen. Usually volcanic activity is much

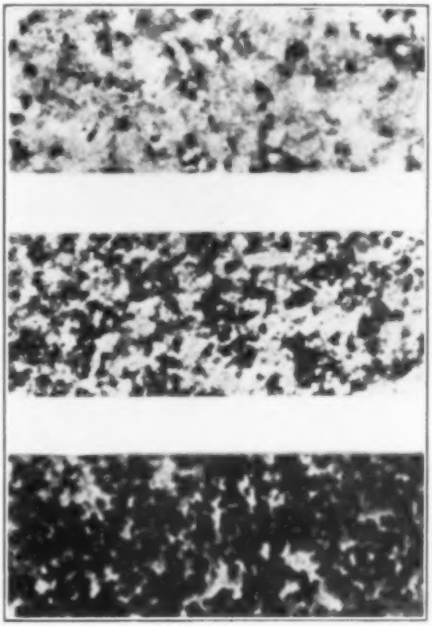

FIG. 1. PHOTOGRAPHS OF POLISHED SURFACES
OF THREE DIFFERENT IGNEOUS ROCKS SHOWING DIFFERENT PROPORTIONS OF DARK MINERALS.

less destructive but scarcely less impressive. At Kilauea in Hawaii and at Namlagira in Central Africa a lava lake forms periodically in the crater pit and, impelled by escaping gases, lava fountains play freely over the surface of the lake. The lava is rock, most familiar to us as the "everlasting hills," but here converted at a high temperature into a substance that behaves almost as water in a park fountain.

At many volcanic orifices the repeated outpouring of lavas and other ejecta has built up a conical pile about the orifice. Such an arrangement of cone with central crater corresponds with the common popular concept of a volcano. In the manner indicated volcanoes often build up to such a height that their peaks are mantled with the eternal snows.

. . . a foreground black with stones and slags,
Beyond, a line of heights, and higher

All barr'd with long white cloud the scornful crags,
And highest, snow and fire.

Tennyson—The Palace of Art.

Yet great piles such as that so vividly painted in these immortal lines are not the most copious expression of surface volcanic activity. In Iceland in 1783 a fissure 20 miles long opened in the earth and lava poured out quietly at many points throughout its extent. This was but one of a series of similar incidents, some historic and some of vast antiquity, as a result of which an enormous thickness of lavas has there accumulated. In the great plateau of India that looks over the Arabian Sea from the Western Ghats a series of lavas with a total thickness as great as one mile is spread over an area of some quarter million square miles. Our own Columbia and Snake River lavas are of comparable extent and thickness.

But even such inundations are insignificant in volume compared with the great masses of molten rock—magma, as it is usually called by geologists—that have invaded the outer layers of the earth without actually reaching the surface, and have there cooled slowly and crystallized to a solid rock. After long ages of erosion the rock cover of many such masses is removed and igneous rock of a deep-seated variety is laid bare. In the Coast Range of British Columbia and Alaska there is a body of that kind some 1,200 miles long, more than 100 miles wide and of unknown but necessarily great depth. Volcanic activity is the mere froth of igneous activity, and the term, froth, is used advisedly, for it is often the expansive force of gases separating from solution in the magma to form bubbles that causes lava to flow out upon the surface. For these reasons I introduced you first to the deep-seated rocks rather than to their more showy relatives.

When the igneous rocks, deep-seated or volcanic, are examined in detail they are found to exhibit great diversity of physical, chemical and mineralogical characters. The lava of Pelée was so stiff that it was pushed through the volcanic orifice as a rigid spine which stood more than 1,000 feet above the crater. The lava lake of Kilauea is characteristically fluid. These differences are connected with differences of mineralogical and chemical composition. Indeed, petrologists have classified igneous rocks into hundreds of types as a result of detailed study of their mineral and chemical characters. The origin of this diversity is the fundamental problem of the igneous rocks. It might be argued, and with some reason, that the ultimate cause of igneous activity is the fundamental problem, but ultimate causes are as elusive here as they are in all natural phenomena. We turn, therefore, to the more tangible problem. It is possible, of course, to assume that different rock types have come into being through special acts of creation or that they have always existed as distinct entities from the beginning of time. But the petrologist finds such assumptions most unsatisfying, not solely on general principles, but because his studies reveal that different rock types found in association with each other often have certain mineral characters in common that point to a family relationship and distinguish them from other associations that show other peculiarities. The natural conclusion reached by the petrologist is that the individual members of any one group have come from a common source and that source is judged to be a common parental magma. From this magma it is supposed that the several rocks of an association have been derived through the operation of the several physical and physico-chemical processes the magma may conceivably have undergone during its career as a liquid mass and also dur-

ing the long period of slow cooling in which it changed from liquid magma to crystalline rocks. It is the task of the petrologist to ferret out these processes and to attempt to evaluate their relative importance.

The petrologist has acquired a great deal of information about rocks as such and this information must ever form the background of any investigation of the processes concerned in their origin. At the same time studies of the rocks themselves are, with respect to the active processes, distinctly post-mortem. This is superlatively true in connection with deep-seated varieties which have necessarily been cold and dead through the long ages of erosion required for their exposure at the surface. Lavas, their surface equivalents, present some little opportunity for the study of live magma, but they are dangerous playfellows and our best acquaintance even with them is as cold rock. All in all, studies of the natural materials, live or dead, raise more problems than they solve.

Laboratory Attack

In the Geophysical Laboratory of the Carnegie Institution of Washington we have sought to throw light upon the general problem by bringing to bear upon it the methods of the experimental sciences. The principal direction the investigation has taken is that of high-temperature research upon rock materials. There is nothing new in such investigations. For a century before the Geophysical Laboratory embarked upon its program, attempts had been made to study the behavior of rock materials at high temperatures. These were, to be sure, somewhat desultory and diffuse, but it was not principally from this cause that little of abiding value was accomplished. Rather was it that, apart from a few notable exceptions, most work of this kind was designed to imitate as closely as possible the actual conditions of nature. Mixtures simulating natural rocks were the subject of experiment, and the investigator thus rushed headlong into a problem almost as complex as that presented by the rocks themselves. Now it is the strength of the experimental method of attack that one can isolate the individual variables of a problem and investigate them separately. Two variables can then be combined, then three, and so on, until, by proceeding from the simple to the complex, one can build up a solution of the general problem with every unit in the structure presumably staunch and true. It is into such channels that Dr. A. L. Day has directed the activities of the Geophysical Laboratory.

The experimental investigation of rocks is a conspicuous example of the cooperative effort of a number of disciplines. The geologist brings to bear upon the problem his experience of rocks in the field. He supplies the natural history of the igneous rocks. The chemist and mineralogist determine the chemical composition of the rocks and of the individual minerals of which they are composed and at the same time measure the physical properties of the minerals. The latter is important because one and the same chemical substance may occur in two or more different forms having quite distinct physical properties. Their discrimination is of the greatest significance because the development of one or another of the several forms of an individual substance depends upon the attendant conditions. The appearance of any one form can thus often be used as a criterion of the conditions of formation, but only, of course, when all factors controlling its appearance have been determined by experiment in the laboratory. The geologist, chemist and mineralogist thus concern themselves with what may be called the materia petrologica.

The physicist brings to bear upon the

Photo by A. L. Day

FIG. 2. LAVA FOUNTAINS IN THE LAVA LAKE OF KILAUEA.

problem his knowledge of high-temperature technique with all that it implies. He must develop suitable apparatus for the obtaining, controlling and measuring of any temperature that may be required. The physical-chemist furnishes the thermodynamic theory that is absolutely essential to the prosecution of such investigations. The petrologist, primarily a geologist, contributes the natural-history setting already mentioned as required of the geologist, and with it a visualization of the broader problem and the capacity to analyze it into sub-problems. He should be expert in the application of the methods of crystal optics to the identification of his synthetic minerals, and should know that, when these methods fail in minutely crystallized substances, he can still turn to x-ray analysis. Ideally he should have a good working knowledge of all the other activities mentioned and be capable of conducting an investigation involving the use of all of them, though he will, of course, require the frequent cooperation of a colleague, expert in one of the branches. In short, he should be a jack of all trades yet master of some, a desideratum that urges tolerance of his shortcomings. Another duty is likely to fall to his lot, that of interpreting the results of his associates to geologists who specialize in other branches but wish to keep abreast of progress in all branches. It is in itself no light task. When he acquires the additional duty of interpreting to the public at large, his cup is to be regarded as indeed full.

Materia Petrologica

The natural setting of the igneous rocks and an indication of the general problem they present have hitherto en-

gaged our attention. Their chemical and mineralogical characters will now be described.

As you know, there are ninety-two fundamental chemical substances or elements. A man-made ninety-third has been announced, but scepticism prevails regarding it, and usually it is supposed that with ninety-two the possible list is complete. Now there seems no escape from the conclusion that all substances in or upon the earth, including even the atmosphere and the material parts of living organisms, must have their ultimate source in the igneous body of the earth. We should expect the igneous rocks to contain all these elements, but if they do, the proportion of the great majority of them is so small that they escape detection by the most sensitive methods. A great many others are present in such amounts that they are determined only by most careful work. Only eight elements occur in rocks in an amount exceeding 1 per cent., and here it must be remembered that we speak of rocks on the average and not of what may be found in an individual specimen. In Table I the ten most abundant elements

TABLE I

AVERAGE ELEMENTAL COMPOSITION OF IGNEOUS ROCKS

Oxygen	O	46.59	Magnesium	Mg	2.09
Silicon	Si	27.72	Titanium	Ti	0.63
Aluminum	Al	8.13	Phosphorus	P	0.13
Iron	Fe	5.01	Sulfur	S	0.052
Calcium	Ca	3.63	Copper	Cu	0.010
Sodium	Na	2.85	Zinc	Zn	0.004
Potassium	K	2.60	Lead	Pb	0.002

in the rocks are listed in the order of their abundance. They make up 99.4 per cent. so that the other eighty-two total only 0.6 per cent. To these ten have been added four others, not because they are next in order of abundance but for the purpose of indicating how small are the amounts of some every-day substances. The familiar metal copper, known even to the ancients, is excessively rare as compared with silicon, an element of considerable importance in metallurgy, to be sure, but unknown to the average individual even to-day. This is, of course, because silicon is obtained from its natural compounds only with great difficulty, whereas copper is sometimes found as such in nature and is readily obtained from its compounds. But this is not the whole story, for, were it not for certain processes of local concentration whereby masses (ore deposits) relatively rich in copper, lead or zinc are formed, the cost of recovery of these and of many other familiar metals, from rocks in general, would be prohibitive, indeed some of them might still be unknown. These processes of natural concentration of ores are of importance in connection with our general problem and we shall revert to them later.

On account of the overwhelming proportion of oxygen in rocks the various elements occur in them almost exclusively as oxygenated compounds and a chemical analysis of a rock is ordinarily stated in terms of oxides of the elements rather than as the elements themselves. The average composition of the igneous rocks stated in this form is given in Table II.

TABLE II

AVERAGE OXIDE COMPOSITION OF IGNEOUS ROCKS

Silica	SiO_2	59.12
Alumina	Al_2O_3	15.34
Ferric Oxide	Fe_2O_3	3.08
Ferrous Oxide	FeO	3.80
Magnesia	MgO	3.49
Lime	CaO	5.08
Soda	Na_2O	3.84
Potassa	K_2O	3.13
Water	H_2O	1.15
Titania	TiO_2	1.05
Phosphoric Oxide	P_2O_5	.30
Manganous Oxide	MnO	.12
all others		.50
		100.00

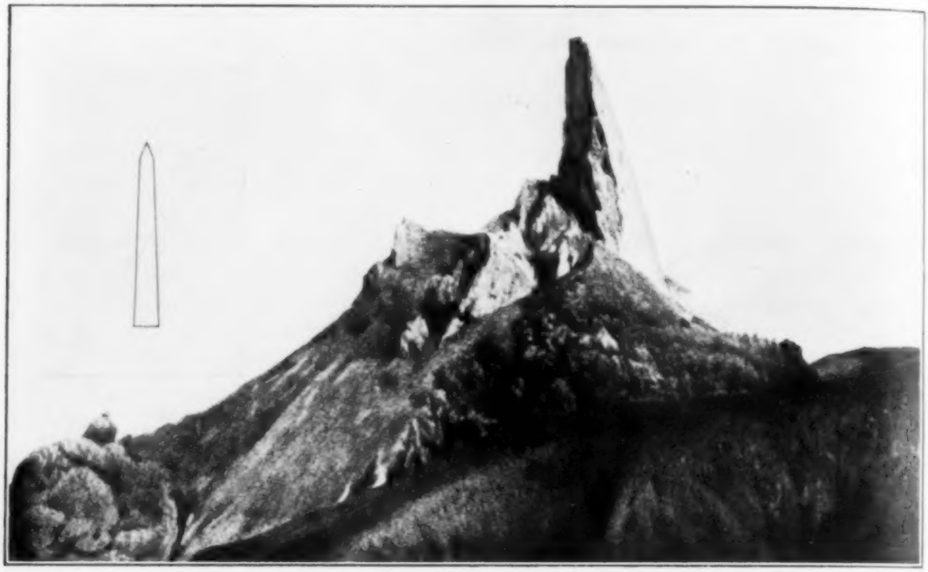

FIG. 3. THE SPINE OF PELÉE (AFTER LACROIX).
A VERY VISCOUS LAVA WAS PUSHED THROUGH THE VOLCANIC ORIFICE TO FORM THE SPINE. *Inset.* THE WASHINGTON MONUMENT ON THE SAME SCALE.

It will be noted that in both tables chemical symbols are given in addition to the name of the element or oxide. Thus in Table I the symbol for oxygen is given as O, that for iron as Fe, and so on for the other elements. In Table II the symbol for lime is given as CaO, of silica as SiO_2, and so on. These symbols convey to the chemist not only the character of the substance itself but also the exact proportions in which the elements are present that make it up. Thus CaO indicates the combination of one atom of calcium with one atom of oxygen, and since the *relative* weights of the atoms are known the exact percentage composition of lime is given when its formula CaO is given. Similarly, the formula for silica, written SiO_2, tells the chemist that two atoms of oxygen are combined with one atom of silicon and he again knows the exact percentage composition by weight. It is important to bear these facts in mind in preparation for an understanding of the more complex formulae that represent the composition of minerals.

Following the discussion of Table I little need be said of Table II. In igneous rocks, taken on the average, only 10 oxides occur in amounts in excess of one per cent. and they total a little over 99 per cent. All other oxides, together with other types of compounds, thus make up less than one per cent.

An igneous magma may be regarded as a mutual solution of the several oxides listed in Table II. No doubt they are, in large proportion, already combined into compounds. Just what these compounds are we can only surmise from the indications given by the crystalline compounds when they solidify, but of definite knowledge of the state of combination in the liquid there is none. Sometimes the liquid magma is cooled so rapidly that no crystalline minerals are individualized. The liquid simply becomes more and more viscous as it cools and even-

tually becomes a rigid substance known as a glass. Such natural glasses are reasonably common. The most common is obsidian, which will be known to many of you through its use by primitive races for arrowheads and spearheads, especially where flint was not available.

It is when magmas cool slowly and individual minerals are formed that they give their most interesting product, the crystalline igneous rocks. The list of minerals that have formed in all the various types of igneous rocks is a rather long one, but, as with rock oxides, only a few are of great quantitative importance. Because silica, SiO_2, is present in such preponderance the mineral compounds formed are for the most part silicates. It will now be our task to examine somewhat closely the common rock-forming silicates.

We may take as a simple example of a silicate the mineral formed when lime, CaO, and silica, SiO_2, combine in unit proportions. The compound $CaO \cdot SiO_2$ results. It may be written alternatively $CaSiO_3$. In either form it tells the chemist or mineralogist the exact relative proportions of calcium, silicon and oxygen contained in it, or, if one prefers, the exact proportions of lime and silica. A simple mineral of this composition is known in rocks, but only doubtfully as an igneous-rock mineral. There are usually other compounds present in a magma that ally themselves with $CaSiO_3$ to give a still more complex mineral compound. When $Al_2O_3 \cdot SiO_2$, or, alternatively Al_2SiO_5, is present, as it is in most magmas, there is formed the so-called alumino-silicate $CaO \cdot SiO_2 \cdot Al_2O_3 \cdot SiO_2$ or, as it may be written, $CaO \cdot Al_2O_3 \cdot 2SiO_2$ or again $CaAl_2Si_2O_8$. This is a very important mineral compound in igneous rocks, constituting one member of the group of minerals called feldspars. It is known as lime feldspar. The two other feldspar-forming compounds are likewise alumino-silicates but are much richer in silica, as their formulae show at a glance. They are $K_2O \cdot Al_2O_3 \cdot 6SiO_2$ (or $KAlSi_3O_8$), which is known as potash feldspar, and the corresponding soda compound $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$ (or $NaAlSi_3O_8$), which is known as soda feldspar.

You will recall that when we made our first acquaintance with the igneous rocks we found that they were made up of different grains, some white or colorless, some in pale shades of red or, rarely, green, and, contrasted with these light-colored constituents, other grains that were black. Now this classification into light and dark minerals, while seemingly of superficial character, nevertheless corresponds, for all practical purposes, with fundamental chemical differences. Of the light-colored minerals the feldspars we have just discussed are the most important, indeed they are the most important of all rock minerals. If we add to the feldspars the mineral quartz (SiO_2) which is also a prominent rock mineral, we shall have included all the light-colored minerals of any great importance in rocks as a whole, though in certain rare varieties other light-colored minerals may be present even to the exclusion of these.

We turn now to the dark-colored constituents of igneous rocks. The dark minerals are iron-bearing and are dark

TABLE III

MOST PROMINENT MINERALS OF IGNEOUS ROCKS

Light-Colored	
Quartz	SiO_2
Lime Feldspar	$CaAl_2Si_2O_8$
Soda Feldspar	$NaAlSi_3O_8$
Potash Feldspar	$KAlSi_3O_8$
Dark-Colored	
Olivines	Mg_2SiO_4 and Fe_2SiO_4
Pyroxenes	mainly $CaSiO_3$, $MgSiO_3$, and $FeSiO_3$
Amphiboles and Micas	complex Fe: Mg silicates
Magnetite	Fe_3O_4

for that reason. Several mineral groups are represented and their chemistry is very complex, but the name, ferromagnesian minerals, which is often given to them as a whole, is a convenient and apt general term. The iron oxides and magnesia are prominent constituents of the dark minerals. They are absent in members of the light-colored class previously discussed.

Of the ferromagnesian mineral groups the olivines, pyroxenes, amphiboles or hornblendes, and micas are those of importance in igneous rocks. The olivines are the simplest. The magnesian olivine is $2MgO \cdot SiO_2$ or Mg_2SiO_4 and the iron olivine $2FeO \cdot SiO_2$ or Fe_2SiO_4. The pyroxenes as a group are richer in silica and in them lime becomes an important constituent. Their most prominent silicate compounds are $CaO \cdot SiO_2$, $MgO \cdot SiO_2$ and $FeO \cdot SiO_2$. The amphiboles are closely related to the pyroxenes in composition and are made up principally of the same compounds. The micas are most complex in character in that they are rich in iron oxides and magnesia but at the same time contain much potash and alumina, oxides that find their greatest prominence in the light-colored minerals. Water is an essential ingredient of both amphiboles and micas. In addition to the iron-bearing silicates, iron oxides as such are represented among the dark minerals, the most prominent being magnetite, Fe_3O_4.

The information regarding minerals that has just been detailed is presented in tabular form in Table III.

This general view of the mineralogy of the igneous rocks is necessarily very incomplete, yet it may afford an acquaintance with them that is adequate for a general appreciation of the problem presented by them. If we turn now to the average igneous rock whose chemistry has already been discussed we find that its mineral composition is that given in Table IV. Although this concept of the

TABLE IV

MINERAL COMPOSITION OF THE AVERAGE IGNEOUS ROCK

Quartz	10
Lime Feldspar	15
Soda Feldspar	32
Potash Feldspar	18
Pyroxene	20
Magnetite	5
	100

average igneous rock made up as indicated in that table is a useful one I would guard you against any false impression you may gain from it. If you should go about to examine rocks and expect to find that all or nearly all specimens you encounter will have a mineral composition approaching fairly closely to this average you have a great surprise in store for you. You will find that in some igneous rocks there is no quartz, in others it may amount to some 40 per cent. Some rocks are made up entirely of olivine yet the majority of rocks contain no olivine. Moreover, the variations are not of random character. For example, an igneous rock rich in quartz is always rich in alkali feldspars and never in lime feldspar. What are the causes underlying such association tendencies and why are there different associations? This is the problem towards whose solution our laboratory investigations have been directed.

LABORATORY METHODS

In the brief mention of the different types of investigation that are brought to bear upon the problem no details of method were given nor can they be given here. Laboratory operations are living processes and are best examined in the life. The details of methods may therefore be taken for granted and a discussion of results may be proceeded with.

The Results of High-Temperature Investigations and Their Significance

Hitherto, it has been possible, in some measure, "to gild the philosophic pill." We now come to a pill upon which, as far as I can find, no coating will take. In order to down it, it is perhaps desirable to adopt the principle of divided doses. We shall break up the pill and take only two or three small fragments now. Those who feel they have derived some benefit therefrom may administer to themselves further doses at some future time.

The presentation of the results of thermal studies of mineral compounds fills thousands of pages in scientific periodicals devoted to that and related matters. In addition, the theory of the subject and the graphical methods of presenting the results that have grown out of that theory are, in themselves, studies which many scientific men have made a life's work. It is no simple task to select from such a mass of material a part that may be discussed in a few minutes, yet shall be a fairly representative sample of the whole and at the same time give some insight into the graphical methods in common use in that connection. Man can do but his best.

A selection has already been made from rock minerals of those that are of outstanding importance. It will be to the thermal studies of these, or rather of some of these, that attention will now be directed. In the general plan of attack it has been the practice to study single oxides first and then to proceed to more complex mixtures. Of the oxides, silica, SiO_2, is by far the most important, occurring as it does in combination in nearly all rock minerals, and also free as the mineral quartz, one of the more important of the light-colored constituents. We shall, therefore, select the oxide of silicon, SiO_2, as that oxide whose thermal properties will receive special discussion.

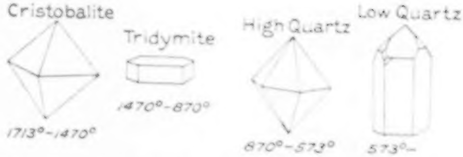

Fig. 4. The stable forms of silica and the temperature range of stability of each. Hand in hand with the difference in crystalline form goes a difference in all other physical properties, yet all are identical chemically and have the composition silicon dioxide (SiO_2).

The Forms of Silica: By heat treatment of one kind and another silica can be prepared in several different crystalline forms. One of these is identical with the natural mineral quartz and is stable at temperatures below 573° C. When it is heated to that temperature it changes promptly to another modification of silica with properties not greatly different from those of ordinary quartz but still distinctly different. The name quartz is used for both, and they may be distinguished as high and low quartz. On cooling high quartz from a temperature above 573° the change to low quartz takes place readily at or very near that temperature, many measurable properties such as volume and optical rotatory power there changing abruptly. Above 870° C. and up to 1470° C. an altogether different form of silica known as tridymite is stable, and from 1470° C. to 1713° C. yet another form known as cristobalite is the stable modification. At 1713° C. cristobalite melts, and from that temperature up to the boiling point, liquid is the stable modification.

The changes from high quartz to tridymite to cristobalite and the reverse do not take place promptly in the manner of the change from low quartz to high quartz. They are in fact very sluggish and either cristobalite or tridymite can be cooled to room temperature without suffering change to the modification stable at that temperature, *viz.*, low

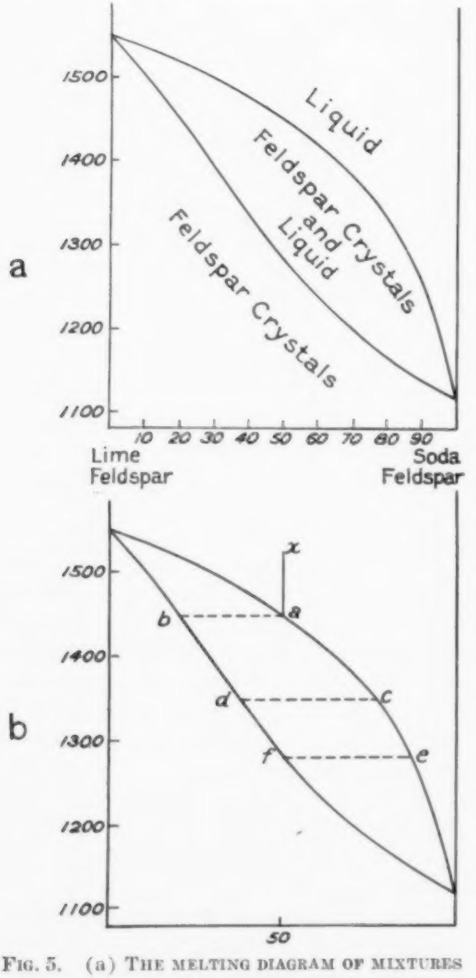

FIG. 5. (a) THE MELTING DIAGRAM OF MIXTURES OF LIME FELDSPAR AND SODA FELDSPAR SHOWING THE TEMPERATURES AT WHICH EACH MIXTURE IS COMPLETELY LIQUID, PARTLY LIQUID AND PARTLY CRYSTALLINE, AND COMPLETELY CRYSTALLINE. (b) THE SAME, SHOWING THE COMPOSITION OF THE CRYSTALS FORMED FROM EACH LIQUID. DURING CRYSTALLIZATION THE RESIDUAL LIQUID APPROACHES EVER CLOSER TO THE COMPOSITION OF SODA FELDSPAR.

quartz. Cristobalite and tridymite do show certain changes of form when so cooled, but these need not concern us here. Two other points of major significance do require mention. The first is that either tridymite or cristobalite can form at low temperatures, especially when the crystals are formed rapidly, although quartz is the stable form at these temperatures. The second point is that quartz in either the high or low modification forms only at the temperatures at which it is stable and never at high temperatures.

Now what do these laboratory results tell us about rocks? In the first place they make it clear that if primary quartz is present in a rock its crystallization from solution in the silicate liquid took place below 870°. On the other hand, if tridymite or cristobalite is present we can not be sure that it crystallized above 870°. Moreover, although all quartz is found upon examination at room temperature to be low quartz, nevertheless there are criteria whereby it can be ascertained in some cases whether it had crystallized above 573° and then changed to low quartz upon cooling or, on the other hand, had simply crystallized directly as low quartz and therefore at temperatures below 573°.

What we actually find in igneous rocks is that quartz is almost universally the form in which silica appears and the evidence is clear that it formed primarily as quartz and not as a secondary product by transformation of cristobalite and tridymite. It is, moreover, frequently possible to show that the quartz had formerly been the high-temperature variety. Thus we learn that the quartz of most igneous rocks and especially of granite, the commonest igneous rock, crystallized from the molten mixture between 870° and 573°.[1] It is frequently possible to show, also, that the quartz of mineral veins, associated with igneous rocks as an aftereffect, never had been high quartz and therefore that it formed below 573°.

Mixtures of Silicates: This discussion of the modifications of silica will serve to

[1] Certain corrections of small magnitude require to be applied to these values if the rocks crystallized under high pressure, but this matter can not be discussed here.

indicate the kind of information that is obtained from the thermal investigation of a single oxide. After oxides are examined simple compounds such as $CaO \cdot SiO_2$ are next attacked, then more complex compounds, such as $CaO \cdot Al_2O_3 \cdot 2SiO_2$, and finally mixtures of compounds. Thus we approach mixtures that are related to actual rocks. The oxide already described being, in the form of quartz, a very important representative of the light-colored constituents, we shall now turn to the results obtained in mixtures of the other prominent light-colored constituents, the feldspars. Lime feldspar, $CaO \cdot Al_2O_3 \cdot 2SiO_2$, melts at 1550° C. and soda feldspar, $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$, at 1122° C. What are the melting relations in mixtures of these two? These have been determined and the results are presented diagrammatically in Fig. 5 (a) and (b). In the diagram temperature is plotted in a vertical direction; the higher up we go from the base of the diagram the higher the temperature indicated. Composition is plotted in a horizontal direction. At the left of the diagram we have pure lime feldspar, at the right, pure soda feldspar, halfway between we have 50 per cent. of each and three fourths of the distance over to the right we have three fourths (75 per cent.) soda feldspar, which means of course that we have one fourth (25 per cent.) of lime feldspar. The nearer we are to the soda feldspar side the more of that compound there is present. The nearer to the lime feldspar side the more lime feldspar there is present. The diagram as a whole shows, then, the exact values of the melting points of the two feldspars and the exact melting interval of all mixtures of them. Thus we read from it that the mixture containing 50 per cent. of each begins to melt at 1287° and the melting is complete at 1450° or, if we are cooling it from a high temperature, such as that represented by the point x, it begins to crystallize at 1450° (point a), and its crystallization is complete at 1287° (point f). In addition the diagram tells us the composition of the crystals that are in equilibrium with any liquid. Thus the crystals that are in equilibrium with the liquid a have the composition b, the crystals that are in equilibrium with the liquid c have the composition d, and so on for other compositions and temperatures. It will be noted that the crystals in equilibrium with any liquid, that is, the crystals that will form from that liquid, are always richer in lime feldspar, and their subtraction will, therefore, always cause the liquid to be enriched in soda feldspar. The composition of the liquid therefore moves to the right along the curve a c as crystallization occurs with falling temperature. Now for a reason that can not be given fully here there is a definite limit to the amount of offsetting of the composition of the liquid in this manner, provided that the crystals remain suspended in the liquid, because the two react with each other or, as it may be put, the crystals absorb liquid and make it a part of their own crystalline substance. It can readily be shown that in such circumstances the liquid will not move beyond e, at which temperature the crystals have the composition f which is, of course, the same composition as the original liquid x or a. But, on the other hand, if the crystals are continually removed from the liquid, its composition will continue to migrate to the right, that is, towards soda feldspar, and there is no limit to this change of composition except the pure soda feldspar liquid itself. The kind of crystallization just described, *viz.*, that during which crystals are continually removed, is called fractional crystallization, and when I determined this diagram more than 20 years ago I was struck by the drastic effects that fractional crystallization could pro-

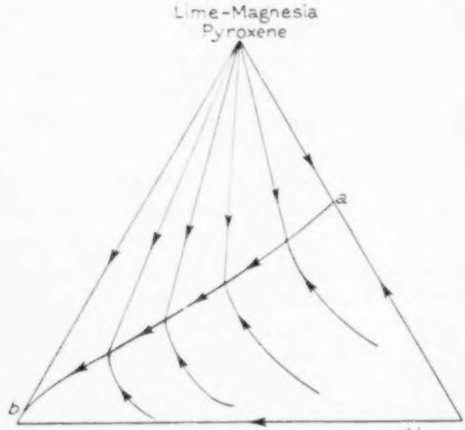

FIG. 6. DIAGRAM SHOWING BY MEANS OF ARROWS THE DIRECTION OF CHANGE OF COMPOSITION OF LIQUID DURING CRYSTALLIZATION OF MIXTURES OF LIME FELDSPAR, SODA FELDSPAR, AND LIME-MAGNESIA PYROXENE. THE LIQUID (*b*), VERY RICH IN SODA FELDSPAR, IS THE GOAL TOWARDS WHICH ALL LIQUIDS TREND DURING CRYSTALLIZATION.

duce in these feldspar mixtures. If we had a liquid mass of such a character in nature, and if during its crystallization the crystals sank under the action of gravity, then, in the part of the mass into which they sank there would be strong enrichment in lime feldspar, and the liquid from which they sank could be enriched in soda feldspar to the near-exclusion of lime feldspar. This is the type of relation that is actually seen in the members of an igneous-rock grouping in nature, in so far as their feldspar content is concerned. No natural magma is as simple as this pure feldspar mixture and many other effects must be going on at the same time as that described, but with this promising indication in mind it seemed desirable to push on from the feldspar mixture to other mixtures of such composition that they would throw light on these possible concomitant effects. Accordingly, a long series of investigations has been instituted, each designed to add its quota of information bearing upon the problem of fractional crystallization in silicate mixtures, with natural magmas ever in mind. A great many have been completed, several are now in progress, and definite plans are afoot for many more.

Remembering that we are still on the subject of the light-colored constituents of rocks and that we have discussed quartz and the lime-soda feldspars, we may now turn to the other light constituent of outstanding importance, *viz.*, potash feldspar. Some details of the relations of potash feldspar are still under investigation, but enough has been done to give a clear picture of the general relations. The results show that while potash feldspar bears a much more complex relation to lime feldspar than does soda feldspar, nevertheless in the effects that fractional crystallization can produce there is no great difference. In mixtures containing all three feldspars both soda feldspar and potash feldspar will be continually concentrated in residual liquids during fractional crystallization. This is again in accordance with the association tendencies of minerals in rock series and we may therefore refer this effect in natural rocks to fractional crystallization unless we find that the other constituents of rocks modify this relation so drastically that the correspondence found, apparently very significant when our information is only partial, should turn out to be mere chance coincidence when our information is more complete.

These other constituents are, of course, the dark minerals, and to these we now turn.

The Dark-Colored Constituents: The dark minerals of rocks are, as already mentioned, the iron-bearing minerals. Of all the elements that occur in rocks in an average amount greater than one per cent. the element iron is the most versatile. It occurs in three ways, as metallic iron itself, which is rare, and in two

different states of oxidation, both of which are abundantly represented. Ferrous oxide, FeO, occurs only in its compounds, whereas ferric oxide, Fe_2O_3, occurs both as such and in its compounds. The oxide, magnetite, Fe_3O_4, is conveniently regarded as a compound of ferrous and ferric oxide, for it may be written $FeO \cdot Fe_2O_3$. All the other common elements occur in rocks only in the oxidized state and as only one oxide.

The versatility of iron proved a stumbling block in the investigation of iron silicates, and for long years they resisted attempts to solve their problems by laboratory methods. The difficulty lay in controlling the state of oxidation of the iron. To keep the iron altogether in the ferric state is usually a simple matter. It is only necessary to have free access of air. But to keep the iron entirely, or almost entirely, in the ferrous state, which is the most important form entering into silicate compounds, is a more difficult matter. Some three years ago I had the good fortune to find a method of investigating the ferrous silicates that is entirely satisfactory. Since then systems have been investigated which throw much light on the iron-bearing olivines and pyroxenes. Before it had been found possible to investigate these iron-bearing minerals, a great deal had been learned of the equilibrium relations of the non-ferrous compounds that enter into the dark-colored minerals, that is, their lime and magnesia compounds, and especially of lime-magnesia pyroxenes. Moreover, lime-magnesia pyroxene had been added to the lime-soda feldspar series and equilibrium relations determined in these complex liquids containing members of the light-colored mineral groups and also members that enter into the dark-colored mineral groups. Details can not be given, but some concept of the results may be gained from the triangular diagram, Fig. 6. In this the curve *a b* may be regarded as marking the bottom of a valley towards which the liquid will flow (as indicated by the arrows) during fractional crystallization and along which it will pass towards its lowest point *b*. We are, of course, not dealing with an actual physical flow of liquid. The diagram is a composition diagram and the arrows indicate the direction of change of composition of the liquid, but the analogy with the physical flow of liquid into and along a valley may serve to make clear the facts depicted in the diagram. Now in this diagram, as in the simpler one (Fig. 5), the same principle applies that the nearer a point representing the composition of a liquid is to the corner representing one of the pure substances the richer the liquid is in that substance. Therefore the liquid *b*, which is the goal towards which all liquids change during fractional crystallization, is very rich in soda-feldspar and very much impoverished in both lime-magnesia pyroxene and lime feldspar. This is a combination of circumstances that natural rocks invariably show, and we are led to entertain seriously the hypothesis that the relations observed in the rocks are due to fractional crystallization.

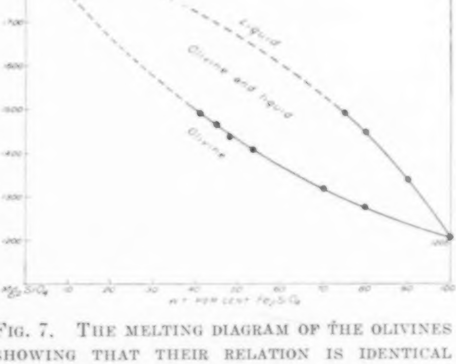

Fig. 7. The melting diagram of the olivines showing that their relation is identical with that exhibited by the lime-soda feldspars (Fig. 5 (a) and (b)).

But still we have not mentioned how the ferrous ingredients of the dark-colored minerals—the very ingredients that make them dark—come into this picture. As yet the relations of the iron-bearing silicates have been determined only within two mineral groups (olivines and pyroxenes). Mixtures of them with light-colored (feldspar) constituents have not yet been studied. But in the olivine and pyroxene groups themselves it is found that the iron-rich member bears the same relation to the other members as does soda (or potash) feldspar to the lime feldspar. This fact is illustrated in the case of the olivines, by their melting diagram (Fig. 7), which is of exactly the same form as the feldspar diagram. In other words, in the dark-colored mineral groups, taken by themselves, there is a tendency for the liquid to become continually enriched in iron compounds during fractional crystallization just as there is a tendency toward alkali feldspar enrichment in purely feldspathic liquids. Therefore the question now arises: What will the net result be if these two effects occur in a single liquid of complex composition? We can not get a residual liquid that has 100 per cent. alkali feldspar and also 100 per cent. iron silicate. What balance is struck between these effects? The full answer to this question will be given only by experimental investigation, most of which is still in the future but some of which is now under way. In the meantime we can, however, be confident of this much, that if crystallization-differentiation is in control, there should be a high ratio of alkali feldspar to lime feldspar in rocks that form from residual liquids, and at the same time a high ratio of iron compounds to magnesian compounds, although we can not yet say what the absolute value of either should be. In point of fact rocks do show that a high ratio of alkali feldspar to lime feldspar goes hand in hand with a high ratio of iron compounds to magnesian compounds.

The trail we have been following appears to be most promising. We are justified in pursuing it further.

By-products

It has been mentioned that many of the most useful metals and other mineral substances are present in excessively small amounts in their source materials, the igneous rocks, and that, were it not for their local concentration in ore bodies, many of them would be scientific curiosities rather than familiar, everyday substances. It is a fact of observation, too, that certain metals tend toward association with certain types of rocks and others with other types, a condition which makes it clear that the factors controlling the derivation of rocks also control the broader distribution of valuable metals. More than this, the formation of actual ore deposits is an after-effect of igneous processes and after-effects can not be thoroughly understood without full knowledge of the processes that precede them and develop into them. Important aid in the location and exploitation of ore deposits is, therefore, a logical outcome of increased knowledge of the processes of derivation of igneous rocks.

The more tangible and more immediate practical utility of thermal studies of rock-forming oxides and silicates derives from the fact that these materials are widely used in a great variety of industrial processes.

Refractory (heat-resisting) substances are essential to such processes. Rock-forming oxides, notably silica, alumina and magnesia, and a few simple combinations of them are the principal refractory substances. They are therefore used as the materials of crucibles, furnace linings and many of the structures which it is necessary to set up in the activities connected with metallurgy, glass-making,

cement manufacture and the pottery and ceramic industry in general. Accurate knowledge of the thermal behavior of the individual oxides and of the manner and degree in which they flux each other when used together is absolutely essential to the most efficient practice in such industries. In all but one of those mentioned the actual products themselves are silicate compounds; in fact, these industries are sometimes grouped together as the silicate industries. Even in metallurgy, where the products won are metals, the slags used to flux away undesired substances are always silicate melts.

Upon all these matters our carefully controlled laboratory investigations furnish information of the utmost practical value. There is a constant flow through our laboratories of men engaged in the industries. They come to observe our methods, to obtain further information upon points not stressed in our publications or simply to express their appreciation. The discovery of mullite, a silicate of alumina, and its identification as the crystalline substance formed when clays are heated has, in itself, placed in a new light the whole subject of refractories formed from clays, which include fire brick, refractory porcelain and even every-day porcelain and pottery. Soviet Russia has had the first of the series of papers upon ferrous silicates translated into the Russian in order to facilitate its use in the many steel research laboratories established by that paternalistic government.

The great body of information upon slags, refractories and the like is an incidental product of our studies, yet there is little doubt that the value of this information to the steel industry alone will, applied through the years, greatly exceed what we received from that industry through the generosity of "the little iron-master."

Conclusion

But we must not let these side-trails lure us from the direct, if untrod, path to our goal. We seek a real understanding of the genesis of igneous rocks, and our path must lie in a broad program of sustained research. A decade or two more may bring us to a point where we can reach adequate appraisal of the hypothesis of fractional crystallization and can visualize the extent to which other processes have cooperated in producing rock diversity. Laboratory investigation of these processes will then be in order. Progress will be slow. There will be pleasant views but nothing spectacular along the way, for it is no stunt-and-gadget program. But through it we may gain increasing knowledge of our Mother Earth.

MATHEMATICS IN BIOLOGY

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I

Is it likely that mathematics, applied to biology, can be of appreciable value in the further development of that science?

This is an intriguing question. It is neither wholly historical nor wholly theoretical. It is at least both.

Some thirty years ago biology took a noticeable tack in the direction of mathematics. Biometry was the port of destination for many ships. Many others used it as an important port of call. Indeed, such an outstanding captain as Davenport spent time and energy in writing a book on mathematics for the use of biologists.

The rediscovery of Mendel's law no doubt had much to do with all this. Here was a direct and outstanding case in which one of the most fundamental phenomena in biology was found to take place according to the simplest mathematics. If one crossed a plant producing wrinkled peas with one producing smooth peas, all the hybrids would produce only smooth peas. But if one self-fertilized these hybrids it was found that on the average three plants produced smooth peas and one wrinkled. Further investigation of this second filial generation showed that two of the three plants that produced smooth peas were hybrids like the parents. One was not a hybrid but was like the smooth grandparent, not only in appearance, but in hereditary make-up. Thus the famous 1:2:1 ratio of Mendel. The finding of such a ratio governing inheritance in living plants and in animals would naturally, and did, stimulate not only research in genetics, but the use of mathematics in biology. Could any find have been happier for this twofold purpose? The ratio 1:2:1 sits in one's mind like hot toddy in one's stomach on a zero day. And if you wish to be completely convinced merely say 1:2:1 aloud, particularly before an audience.

But such is life that its continued observance, up to a certain point at least, seems to make it more complex rather than more simple. Such a large number of the skippers in the race saw the full sails of the then few genetics yachts that there was a general movement in that direction until hundreds of yachts were taking advantage of the freshening breeze Mendel had found. Under such conditions it is not surprising that in the last thirty years the course followed by these boats has become fairly well charted. This charting has led to the discovery that the 1:2:1 ratio is the exception, rather than the rule; that, indeed, there is no general mathematical rule. Gradually research in modern genetics has been moving away from quantitative study and expression. The simple algebraic formulae of a couple of decades ago are almost wholly absent from the literature. Genetics, upon coming of age, has become more and more qualitative. A large impetus in this direction was given by the discovery that mutations could be induced by x-rays. With the recent discovery of the suitability of the salivary gland chromosomes of *Drosophila*, the present leaders of the race are well-nigh all using the same new qualitative spinacker. No wonder, for it is a marvelous experience to actually see the locus of a gene deficiency in a chromosome.

Biology's most quantitative, non-hyphenated subdivision can not become qualitative without a serious repercussion in the whole science of biology.

Furthermore, the process of genetics' becoming qualitative has perhaps not been so sudden as I may have implied. Already fifteen years ago, I remember hearing a leading geneticist quoted as saying, "Biomathematics is a snare and a delusion."

It was even then obvious that while the inheritance of single, relatively unimportant characteristics might be easily amenable to simple mathematical prediction, fundamental physiological life processes did not seem to fall within the group. The factors involved appeared to be so many as to be beyond the simple statistics and probabilities of a biological laboratory. Furthermore, there was a growing question among geneticists of how far it was desirable to extend the knowledge of the inheritance of relatively unimportant characteristics. It was no longer startling news to find that inheritance of a given character in one animal or plant was similar to, or different from, that in another animal or plant.

Added to this, the idea of emergent evolution received appreciable attention. It was pointed out that two organisms, bred to each other, might produce an offspring which was neither the addition, nor a mosaic, of the two. It was further stressed that similar happenings were characteristic of all nature, inorganic as well as organic. Thus two gases, hydrogen and oxygen, when united in the right way, gave a very different third thing, water. And so on indefinitely. Now that heavy water has been discovered, perhaps the case is even more striking.

There are other important examples of the decline of mathematics in non-hyphenated biological sciences. The decline of physical anthropology is outstanding. Its offspring, growth of man, a study which has been extended until it includes the simplest animals and plants, is an excellent case in point.

Obviously, one very direct way of studying growth is to study it quantitatively. It is a very simple thing to make measurements of the growth of a person, other animal, plant, or parts of any of these. Such measurements naturally lend themselves readily to expression in mathematical terms. They give material for studies in an important part of the theory of probability: statistics, including sampling, correlation and dispersion. The data on growth are so numerous and so quantitative as to invite the attractive mathematical exercises of curve-fitting and the writing of formulae.

Such obvious possibilities have been, of course, irresistible. Many of the sailboats of mathematics-in-biology have steered their course to take advantage of the strong breezes coming from studies of growth. One might think that such strong breezes would put the mathematics-in-biology boats well in front. Almost the opposite has been the case. Indeed some of the leaders in this particular race have nearly come to the conclusion that they are caught on the edges of an air-pocket. They begin to believe that the breeze, though strong, is circular; that they are going nowhere at a fast clip.

This probably is the reason for Professor Edwin B. Wilson's[1] remarks in Volume II, Cold Spring Harbor Symposia on Quantitative Biology (1934). "One may orient oneself by some axioms or platitudes. I. *Science need not be mathematical.*" "II. *Simply because a subject is mathematical it need not therefore be scientific.*" "III. *Empirical curve fitting may be without other than classificatory significance.*" "IV. *Growth of an individual should not be confused with the growth of an aggregate (or average) of individuals.*" "V. *Different aspects of the individual, or of the average, may have different types of growth curves.*"

[1] Cold Spring Harbor Symposia on Quantitative Biology, Volume II, p. 199, 1934.

These last two headings are particularly based upon Davenport's work and conclusions. In the same volume Davenport[2] recalls some of these conclusions. "Since the hypothesis of autocatalysis relates to individual growth and not merely to mass statistics, and since no individual grows the way shown by mass growth curves, Robertson's conclusion was based on incorrect premises, and had no validity." And further, "Were there a growth-activating factor that acted on all parts of the body at the same time we might lay more stress upon the curve of body growth. But we know that the different organs grow at different rates and their maximum periods of growth occur at different times."

To make the case even more conclusive we might quote all the printed discussion of Professor Wilson's paper. The interested reader should certainly refer to it. This should be done with the realization that participants in Cold Spring Harbor Symposia on Quantitative Biology are particularly interested in the notions behind the symposia, implied in their name. With this in mind one gets a fair picture of a wide-spread disappointment in the results of the use of mathematics in the study of growth. The first sentence of Eric Ponder's[3] remarks in the discussion is significant.

> "One point upon which there seems to be pretty general agreement is that there is little relation between the amount of work which has been done on the mathematics of growth and the clarification of the subject which has resulted."*

[2] *Ibid.*, p. 203.

[3] *Ibid.*, p. 201.

*A very striking confirmation of the decline of the use of mathematics in biology, particularly in respect to biometry, is given in a note published in *Science* since the manuscript of this paper was first prepared. George G. Scott (*Science*, 81: 253, March 8, 1935) tabulated the distribution of papers in biological sciences for the past eight years, as determined by 169,744 papers received in *Biological Abstracts*. From this it appears that biometry occupies the last place in the list, accounting for 0.21 per cent., or 356 of the 169,744 papers. Scott among his conclusions justly says, "Biometry appears to be in a state of real *depression.*"

II

The picture is indeed rather depressing. But, to quote Professor Wilson again, "One may orient oneself by some axioms or platitudes," and to adopt his admirable style, we may arrive at something like the following.

I. *Mathematics can not produce valuable generalities, laws or formulae in biology when the data which it uses are insufficient.* The biological data concerning growth are very incomplete. The factors which influence the growth of a whole organism, or any part thereof, are very numerous, very incompletely understood or measured, and some almost unknown. Growth is indeed one of the most complex expressions of life processes. Extensive use of mathematics as a means of finding the explanation of such a complex and incompletely understood expression would appear, *a priori,* to be untimely, save as a pastime.

II. *Mathematics is of value in even very limited areas in which sufficient data are at hand.* Mendel's 1 : 2 : 1 ratio was found to be the exception, rather than the rule, for the inheritance of the great majority of distinguishable characteristics of an organism. Nevertheless, without the simple mathematical statement of Mendel's work, and of other early work in genetics, the unprecedented incentive to research in genetics would have been lacking, as it had been for hundreds of years. The obvious result would be non-existence of the impressive modern body of knowledge of genetics. There can be no question that all this body of knowledge has as its forebear Mendel's simple mathematical law.

III. *Mathematical expression of biological findings in terms of laws or equa-*

tions, gives significance to so-called negative findings. It is very difficult to recognize exceptions to an unexpressed law. In genetics, crossing-over, non-disjunction, deficiencies, multiple factors, indeed the long list of terms and concepts without which there would be no modern genetics, have no significance save as exceptions to Mendel's, or other simple mathematical, laws. The salivary gland chromosomes of *Drosophila* were observed years ago. The significance of the present qualitative studies upon them rests wholly upon exceptions to Mendel's law.

IV. *Mathematics may serve as a valuable measure of the state of completeness of knowledge of a science or a part of a science.* The comparative failure of the use of mathematics in interpreting findings in studies of growth indicates the colossal mass of our ignorance in respect to causes of, and factors in, growth. It should be an important stimulus to further work. Words often serve as a presentable cloak for very incomplete knowledge. Mathematics, being of scantier material, is more likely to show the skeleton lurking beneath. A biologist may smile understandingly and benignly at, "and finally, this reaction may depend upon a few other factors the nature of which we do not understand at present." He is likely to completely disregard the statement, to consider the problem well-nigh solved and to turn his attention to something else. But let the same notion be expressed by β as the known, and $f\ \lambda\rho\pi$ as the "few other factors the nature of which we do not understand at present." The biologist will now have reached the energy of activation. He will think, "The audacity of that one to assume that we will accept an equation with three unknown variables." He may even continue with his work in an attempt to reduce the functions of these variables to known quantities.

III

In a very able and readable paper a few years ago, Weaver,[4] writing on "The Reign of Probability," quotes Laplace in the introduction of his "Théorie analytique des probabilités," as follows:

> "Strictly speaking one may even say that nearly all our knowledge is problematical; and in the small number of things which we are able to know with certainty, even in the mathematical sciences themselves, induction and analogy, the principal means for discovering truth, are based on probabilities; so that the entire system of human knowledge is connected with this theory."

The fact that applied mathematics is, after all, only a matter of probabilities no doubt upsets many biologists. They are beset by complex problems in much of their research, and are constantly face to face with unknown variables. In such a working environment it would be pleasant to have some security to which one might turn as to rest billets. It would be most fortunate if the introduction of exact sciences, chemistry, physics and mathematics, into biology produced such rest billets. But it can not, for reasons pointed out by Laplace, and elaborated in clear detail by Weaver. It is obviously disappointing that facts, even in the most exact sciences, are based on probabilities. And disappointment is even greater perhaps, because too much has been expected of the use of mathematics in biology.

My personal opinion is very strong in favor of making every practicable use of exact science in biology. Probabilities are as useful here as elsewhere. Mendel's 1:2:1 ratio is itself, of course, based on probabilities. If one took a pod containing four peas resulting from a cross of "pure" smooth with "pure" wrinkled—the probability of obtaining a 1:2:1 ratio from the four hybrid seeds would be very, very slight. But

[4] THE SCIENTIFIC MONTHLY, November, 1930, p. 464.

if one had a million such pods and grew all four million resulting plants, the chances of obtaining very approximately a 1:2:1 ratio would be very good indeed. Such probabilities, if not all we need in biology, are certainly all we can expect. The fact that applied mathematics deals wholly in probabilities should in no way lessen its usefulness to biology.

There are numerous examples of the usefulness of mathematics in biology. In addition to its stimulating value to genetics, and its restraining value in the interpretation of studies on growth, which we have already mentioned in detail, a very pretty example is to be found in the history of research on the process of photosynthesis.

It is known that in ordinary chlorophyllous plants, such as sunflowers, carbon dioxide diffuses into the leaves through stomata, or holes, in one or both of the surfaces of the leaf. A difficulty of the theory, when originally proposed, was that CO_2 diffused into leaves at a rate appreciably greater than would be expected from data of the rate of CO_2 absorption on an exposed, receptive surface of known area. Due to attempts to explain this mathematical discrepancy the "diameter law" was discovered, largely as a result of the work of Brown and Escombe.[5] This law, involving diffusion gradients, is interesting not only to plant physiologists, but to other biologists, chemists, physicists and mathematicians.

The use of the theory of probabilities in biology has recently had a very lucky and impressive demonstration in the synthesizing of sex hormones from various other sterols[6]—a procedure which may be considered quite as mathematical as chemical.

[5] See H. A. Spoehr, "Photosynthesis," The Chemical Catalog Company, New York, 1926.

[6] See review by Charles E. Bills, *Physiological Reviews*, Volume 15, p. 1, 1935.

IV

It would seem to be self-evident, from the history of chemistry and physics, as well as from the history of biology, that there is likelihood that applied mathematics in biology can continue to be of appreciable value. I will extend this farther, and say that it appears to me that one may expect sufficiently valuable returns from a theoretical biology, based on mathematics, to justify its birth and controlled nurture; this in spite of the fact that there are plenty of examples of the failure of such a procedure in the past.

Various opinions are held of theoretical biology, its scope and purpose. An indication of one of these opinions may be obtained from the following remarks in a recent paper by Rashevsky:[7]

> If, however, we entertain the hope of finding a consistent explanation of biological phenomena in terms of physics and chemistry, this explanation must of necessity be of such a nature as the explanation of the various physical phenomena. It must follow logically and mathematically from a set of well-defined general principles. The collection of experimental facts gives us a lead for the establishment of the general principles. But the question as to whether a phenomenon or a set of phenomena follow from a certain experimentally established principle is in general beyond the reach of the experiment. Only in some very elementary cases can a direct inference of that nature be made from a set of experiments. In the vast majority of cases the answer to such questions belongs to the domain of deductive science. No experimenting, no matter how careful and exhaustive, could have ever established that the variation of the mass of an electron with its velocity, according to the well-known Lorentz formula, *is a consequence* of and follows from, the group of experimentally established facts leading to the principle of relativity of motion. The experimentally established impossibility of observing absolute motion on one hand, and the experimentally established fact of the variation of the mass of an electron according to a certain formula on the other hand, would have constituted two sets of unconnected facts. It required the

[7] Cold Spring Harbor Symposia on Quantitative Biology, Volume II, p. 188, Cold Spring Harbor, N. Y.

mathematical analysis by a theoretical physicist to *demonstrate* that the two sets of facts are in reality two different manifestations, two different consequences, of the same general principle.

In view of that said above it is only natural to assume that the lack of our knowledge of the fundamental causes of biological phenomena, in spite of the tremendous amount of valuable facts, is due to the lack of use of deductive mathematical methods in biology. This is being realized more and more every year and these symposia are proof of this realization. But as there are no royal roads in mathematics, we should not expect this application of mathematical methods to biology to produce miracles and to solve with one stroke all fundamental questions. In theoretical, as in experimental, research a great deal of preliminary work is necessary before final results are reached. Besides, in its future development the theoretical research will have to go hand in hand with the experimental, and ask of the latter information which may not yet be available, and for which the experimental scientist would even not have looked.

There are certain statements in this point of view to which I find it not difficult to subscribe. It is likely that at some time an appreciable number of life processes will be described in physical and chemical terms. These will then have been explained, provided physics and chemistry will have developed far and fast enough to provide the explanations. Even without bringing in analogies in physics one would seem to be justified in saying that deductive mathematical methods should have some value in helping us reach this stage. It is further pleasant to think of theoretical research asking information from the experimentalist for which the latter "would even not have looked." There is a possibility that such questions might be very useful at times. There are obviously, however, difficulties in putting it in practice immediately upon a large scale. Even when Rashevsky applies it to cell division we find the following comment from Davenport:[8]

I think the biologist might find that whereas the explanation of the division of the spherical cell is very satisfactory, yet it doesn't help as a general solution because a spherical cell isn't the commonest form of cell. The biologist knows all the possible conditions of cell form before division; cases where the cells increase enormously without dividing, and divide without increasing in size. There doesn't seem to be in any general way a relationship between the form or size in connection with the cell division. In the special cases of egg cells and cleavage spheres, this analysis may prove very valuable. But after all, these are only special cases.

To this Rashevsky[9] replied:

I have insisted on several occasions that the results presented today are only the first steps in the development of mathematical biology. It would mean a misunderstanding of the spirit and methods of mathematical sciences should we attempt to investigate more complex cases without a preliminary study of the simpler ones. The generalization of the theory, to include non-spherical cells, is indeed needed, and this will be the subject of research after the simpler cases are thoroughly and exhaustively studied. A few preliminary investigations of simplest non-spherical cases show that qualitatively the results presented today remain unchanged. To my mind it is already quite a progress, that a general physico-mathematical approach to the fundamental phenomena of cellular growth and division, as well as development of multicellular organisms, has been shown to be possible. Judging by the development of other mathematical sciences, I would say that it will take at least twenty-five years of work by scores of mathematicians to bring mathematical biology to a stage of development comparable to that of mathematical physics.

V

Meanwhile, it would seem fair to conclude that theoretical biology, in the sense outlined, should receive some attention as a definite part of biology. I would suggest that half a dozen chairs for theoretical biologists be established at biological laboratories. It has been suggested that these chairs be distributed as follows: three in this country, one in England and two on the continent. It would seem preferable to establish such chairs at research institutions, in so far as is feasible. If, however, some are established in universities, it

[8] *Ibid.*, Discussion, p. 197.

[9] *Ibid.*, p. 198.

should be clearly understood that courses should not be given in theoretical biology. This should be understood for several reasons. The holder of the chair should have as much time as he can possibly use for study and deduction. Furthermore, a professor must be uninspiring indeed who, regardless of his desires, does not, by his teaching alone, beget a number of mental sons and daughters. There are many reasons to believe that we do not wish a flock of newly hatched and hatching theoretical biologists at this time or within the next ten years, at least. What we wish is half a dozen brilliant minds to further explore the possibilities of theoretical biology, and to be in a position to become the chiefs of staff if and when recruits are needed.

Many a good thing has been run into the ground because too many hounds followed it too closely and gave too much voice to the chase. To return to our metaphor of the sailboat race, the tendency among biologists to abandon the course they were sailing in order to catch a freshening breeze somewhere else has been altogether too marked. We are too frequently given the spectacle of a large group of fairly good boats becoming relatively becalmed because there are more sails to fill than there is breeze to fill them. It seems sometimes like twelve little boys fishing. One little boy catches a good-sized fish and in no time eleven lines are within a few feet of his own, whereas the other big fish are quite likely in other parts of the lake. If we apply the theory of probabilities to theoretical biology we shall find, no doubt, that it will be wise not to expect too much from the science too soon. Consequently, we should see to it that the number of men who receive support for work in theoretical biology be kept small for the time being.

From this it should be apparent that I advocate taking no glamor, support or troops from the well-established and already very productive branches of biology. What is suggested here is to give a new branch of the service a reasonable and friendly test. It seems wholly fair to think that if we do this we shall find that mathematics, even in a relatively fundamental sense, will from time to time be of use to biology.

THE EDUCATIONAL AND OCCUPATIONAL ATTAINMENTS OF OUR NATIONAL RULERS

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THE United States, in contrast to the older countries of Europe, has been permeated with the philosophy of rugged individualism. Its rapid industrial expansion is considered the achievement of a free people unhampered by economic, social or political barriers to individual progress. No caste is said to exist, and no privileges of birth or breeding can prevent the capable boy, however lowly his origin, from reaching that enviable place in life which his abilities make possible.

Especially is this believed true in the political world. Despite the scientific evidence of biology and psychology concerning the differences among men, their political equality is guaranteed in a constitution which prescribes a representative government. Those who govern must be chosen from among us, and, if the channels of vertical movement have not become clogged during the years of our historic development, there is freedom enabling representatives of the people to rise from the humble position of the masses to the highest seats of government. If this condition prevails, our democracy has achieved a truly representative character.

But what are the facts supporting or denying the representativeness of our governing bodies? Research in this important field is scanty, probably because of the fragmentary character of usable sources. The present study is limited for this reason to an analysis of Presidents, Vice-Presidents and cabinet officers, who make up the official rulers of our commonwealth.[1] Though controlled by law, nevertheless they are the executives conducting the nation's business. Only the President and Vice-president offer themselves for the selection of the people, yet the cabinet officers chosen to make up their official families have been approved by these elected officers. They are representative of the views and aspirations of their Presidents and the political parties in which they share common membership. Consequently, they are classed with the Presidents in the eyes of the people; together they constitute the political rulers of the United States.

DISTRIBUTION OF AMERICAN RULERS

In Table I a distribution is given of the American rulers studied. A totals column has been retained in all succeeding tables, which gives the figures for all rulers from the first presidential cabinet

[1] The following sources have been consulted: "Appleton's Cyclopaedia of American Biography," edited by James Grant Wilson and John Fiske, D. Appleton and Company, New York, 1888; "Biographical Dictionary of the American Congress, 1784–1927," U. S. Govt. Printing Office, Washington, D. C., 1928; "Dictionary of American Biography," edited by Allen Johnson, Charles Scribner and Sons, New York, 1928; "The Encyclopedia Americana," The American Corporation, Chicago, 1925; "The National Cyclopaedia of American Biography," James T. White and Company, New York, 1898 to 1930; "Who's Who in America," A. N. Marquis and Company, Chicago; files of the *Army Recruiting News;* files of the *Congressional Record.*

in 1789 to the present one. Trends have been depicted by breaking up this total into periods having historic significance. The first period from 1789 to 1824 has been designated the "Colonial" with the thought that it encompasses those years when the colonies were breaking away from England and establishing the national government. The second portrayal is the "Commoner Period," ushered in by the Jacksonian democracy in 1825 and extending to Hayes' administration in 1877. During this time our westward movement took place and the spirit of the frontier dominated our national life. The third period is the "Modern," extending from 1877 to 1934. It has been called the "Plutocratic Period," by some writers because it covers the span of our big business development.

It has been necessary to complicate the tables in some instances by adding percentage columns for use in making comparisons of one period with another, inasmuch as the length of periods and numbers of individuals in each are not always the same.

TABLE I

DISTRIBUTION OF AMERICAN RULERS

Periods	Totals: No.	Totals: Per cent.	Number of rulers: Presidents	Number of rulers: Vice-presidents	Number of rulers: Cabinet officers
All rulers 1789–1934	368	100	31	23*	314
Modern period 1877–1934	176	47.8	13	11	152
Commoner period 1825–1876	144	39.1	12	7	125
Colonial period 1789–1824	48	13.1	6	5	37

* As some Vice-presidents became Presidents they appear in the Presidents column, and not here.

EDUCATION OF AMERICAN RULERS

Do our American rulers represent the average educational attainments of our people or are they a select body of men? The facts are presented in Table II.

The table reveals the fact that American rulers have always been far above the average educational level of the populace at large. Even in the commoner period, when the average education of the general population was not above the common school, almost 87 per

TABLE II

EDUCATION OF AMERICAN RULERS

Type of education	Number of rulers: All rulers	Modern	Commoner	Colonial	Per cent. of rulers: All rulers	Modern	Commoner	Colonial
Totals	368	176	144	48	100	100	100	100
College or university graduates	236	126	85	25	64.1	71.6	59.0	52.0
Attended college but not graduated	32	13	12	7	8.7	7.3	8.3	14.7
Academy or secondary school	56	18	28	10	15.2	10.3	19.5	20.8
Common school (elementary)	36	16	15	5	9.8	9.1	10.4	10.4
Limited schooling (part of elementary)	6	3	2	1	1.7	1.7	1.4	2.1
No formal schooling	2	0	2	0	0.5	0.0	1.4	0.0

cent. of the rulers had been trained in the academy, college or university. From the origin of the republic to the present administration the typical ruler has always been a college graduate.

The channel of vertical movement through which one mounts from the low levels of social origin to such high places as are occupied by rulers are not entirely closed to those so unfortunate as to possess little formal schooling. In each of the three historic periods a few individuals, 8 of the 368 rulers, have been able to overcome this handicap to win in the race for rulership.

The 10 to 12 per cent. of rulers who have not had the advantages of exceptional schooling have made use of other channels of upward movement. Of the 48 rulers who had only common school training or less, 19 were lawyers; 7 editors, publishers or authors; 4 were laborers; 1 was a farmer, and 1 a doctor of medicine. All were the product of a young, virile country in which training for the professions could be secured during apprenticeship, and where business talent could achieve eminence in an expanding industrial order which had little regard for educational or social backgrounds.

Only one poorly educated farmer succeeded in rising above his fellows, and three of the four laborers who became members of the ruling group were secretaries of labor who were chosen because of their rise to positions of power in the labor movement.

Harvard University has trained more rulers than any other institution. Only three other universities have trained more than ten rulers, namely, Yale, Princeton and North Carolina. Thirteen universities have each graduated five or more men who became rulers.

The only presidents who emerged from the masses of citizens possessing little formal schooling were four who held office during the commoner period of our history. Since the days of Johnson just following the Civil War there has not been a person occupying the White House whose educational attainments were representative of our people. From Hayes in 1877 to Franklin Roosevelt to-day, twelve of the thirteen presidents have been college trained. All thirteen have had secondary education, a degree of schooling to which only 10.2 per cent. of our population had attained by 1932.

The education of our Presidents is as follows:

Education	Total	By periods: Modern	Commoner	Colonial
College graduates	19	10	5	4
Attended college	4	2	1	1
Academy (Secondary)	4	1	2	1
Common school	2	0	2	0
No formal schooling	2	0	2	0

Occupations for Which American Rulers Were Trained

To make comparisons of occupations over a period of 144 years of a rapidly growing nation's life is not possible in other than relative terms, for an occupational designation, its training, income and social prestige, might have undergone significant changes during that time. Therefore, the material submitted to the reader on the occupations of our rulers has been assembled with extreme care. Groupings have been made which denote as nearly as possible distinct occupations arranged in upper and lower levels. Such a procedure permits the classification of occupations for the whole range of time, because within themselves the levels combine occupations which have had similar social connotations for the several historic periods of our national existence.

The upper level comprises professional, proprietor, managerial and large

landed proprietor occupations. While there are undoubtedly distinctions of considerable magnitude between these occupations, nevertheless they possess a certain homogeneity of cultural patterns, as expressed in relatively high incomes, prestige and similar social habits which mark them off distinctly from the manual labor occupations, small farmer and clerical workers. These latter comprise the lower level occupations, having also a similarity of cultural patterns revealed in low incomes, little social prestige and inferior cultural habits. It is impossible to push these classifications too far, for they are not infallible. Yet they are in a rough way indicative of the social significance of occupations

TABLE III

OCCUPATIONS FOR WHICH AMERICAN RULERS WERE TRAINED

Occupation	Number of rulers				Per cent. of rulers			
	All rulers	Modern	Commoner	Colonial	All rulers	Modern	Commoner	Colonial
Totals	368	176	144	48	100	100	100	100
Proprietors	37	22	9	6	10.0	12.5	6.2	12.5
Merchants	17	6	5	6				
Manufacturers	9	6	3	0				
Bankers and financiers	11	10	1	0				
Professions	310	144	128	37	84.0	81.8	88.9	77.1
Lawyers	272	121	118	33				
Publishers and editors	17	13	4	0				
Physicians	8	3	1	4				
Professors	5	3	2	0				
Writers	2	0	2	0				
Sociologist	1	1	0	0				
Professional-gentleman	1	0	1	0				
Managerial	4	1	3	0	1.1	0.6	2.1	0.0
Army officers	4	1	3	0				
Clerical	2	2	0	0	0.5	1.1	0.0	0.0
Private secretaries	2	2	0	0				
Agricultural	12	4	3	5	3.3	2.3	2.1	10.4
Large landowners	7	0	3	4				
Farm operators	5	4	0	1				
Manual laborers	4	3	1	0	1.1	1.7	0.7	0.0
Miners	2	2	0	0				
Tailor	1	0	1	0				
Transportation worker	1	1	0	0				
Total from upper levels	362	171	143	48	98.4	97.2	99.3	100.0
Total from lower levels	6	5	1	0	1.6	2.8	0.7	0.0

and prove extremely helpful in determining the levels from which our rulers emerge.

In Table III the occupations of American rulers have been listed, and grouped into upper and lower levels on the basis just described.

Almost 100 per cent. of all rulers come from the very peak of the occupational pyramid. Rulers are chosen from among the professions in the majority of instances. Lawyers have always possessed an entrée to political life, and this occupation still offers the easiest method of acquiring training useful in securing political appointment. The proportion of lawyers in each historic period has been high, being 68 per cent. in the modern period, 82 per cent. in the commoner and 68 per cent. in the colonial.

In terms of occupations for which they were trained presidents have been selected from the common walks of life in only one instance. The facts are as follows:

Occupation	Total	By periods		
		Modern	Commoner	Colonial
Lawyers	21	8	8	5
Army officers	3	0	3	0
Politicians—government office	2	2	0	0
Landowners	1	0	0	1
Professor	1	1	0	0
Engineer	1	1	0	0
Newspaper editor	1	1	0	0
Tailor	1	0	1	0

Comparison of Occupations of Rulers with the Occupations of Their Fathers

It appears that our rulers are a very select portion of our population from both an educational and occupational standpoint. Perhaps this is a most commendable condition, for naturally our most talented citizens should rule us. It might well be that in the United States educational opportunities are available to all who have capacity to profit thereby, irrespective of their economic or social status. The high occupational level which rulers have achieved might well represent the result of their efforts in fair competition with others. Consequently, their attainments would offer testimony to the working out in practise of our democratic principles. They would reveal what can be done when the channels of upward movement are kept open so that talent, regardless of original social position, may emerge in high place through having secured training and exhibited capacity.

Or perhaps the reverse is true, and it may be that rulers did not start from "scratch" but have had the aid of fathers or friends in substantial form, which gave them an undue advantage over all other citizens in the race for power. If such be the case, we would have little reason for self-praise, because no great measure of democracy had been achieved. We would therefore face the necessity of altering the social structure sufficiently to enable talent wherever it is located on the social pyramid to secure training and express itself.

We are unable to establish either proposition without the facts. Some of them may be ascertained from a comparison of the occupational status of rulers and their fathers. This comparison will reveal the amount of occupational climbing that has taken place, and, to the extent that occupations signify social status, the rise in social status of sons as compared with fathers. If this rise is great in amount, the democratic principle would seem to be working out well. If small and circumscribed, little upward movement would

be indicated, in which extremity we would face the necessity of enacting a sound public policy which would alter conditions in the interest of a truer democracy.

Whenever data were not sufficiently clear to permit of the tabulation of the occupations of both father and son, they were eliminated. In all 84.5 per cent. of the 368 rulers could be used, divided as follows:

Period	Total	Usable data No.	Usable data Per cent. of all rulers
1789–1934	368	311	84.5
Modern period	176	141	80.1
Commoner period	144	127	88.2
Colonial period	48	43	89.6

While most studies of occupational inheritance stress the term "identical occupation" of father and son, it probably has little social significance. Whether the father is a doctor of medicine and the son becomes a lawyer is not so important as whether the occupational status which the son achieves is higher, lower than or equal to that of his father. Climbing is not denoted by identical or dissimilar occupational designations, but by whether the level of occupation is identical or different in terms of social prestige, cultural status and purchasing power.

In Table IV the occupations of fathers and sons are compared. In the United States, where until 1870 over 50 per cent. of the gainfully employed were working in agriculture, where an increasing population was moving westward to occupy free land all during the eighteenth and nineteenth centuries, it is natural to expect that a large percentage of rulers would have farmer fathers. Farmers furnished more sons who became lawyers than any other occupation in which fathers were engaged, yet farmers contributed less than a third as many lawyer sons as the upper levels of occupation combined. Characteristically, therefore, rulers whose occupation is the law have been recruited from

TABLE IV

COMPARISON OF RULERS' OCCUPATIONS WITH OCCUPATIONS OF THEIR FATHERS

Occupations of rulers	No. of rulers	Number of fathers in occupations: Lawyer	Business and finance	Army officer	M.D.	Professor	Journalist	Preacher	Govern-ment official	Planter	Farmer	Clerical	Manual laborer
Lawyer	232	46	36	5	20	7	4	10	1	35	63	...	5
Business and finance	31	3	18	1	1	...	2	1	1	...	3	...	1
Army officer	5	1	...	...	...	...	...	1	...	2	1	...	...
M.D. (physician)	6	1	1	...	1	...	...	...	...	...	3	...	...
Professor	5	...	...	...	...	...	...	2	...	2	...	...	1
Journalist	15	...	3	...	1	...	5	1	...	...	3	1	1
Engineer	2	...	1	...	...	...	...	...	...	...	...	...	1
Government official	2	...	1	...	...	...	...	...	1	...	...	...	...
Planter	5	1	...	...	...	...	...	...	...	4	...	...	...
Farmer	4	...	1	1	...	...	...	...	...	...	2	...	...
Manual laborer	4	...	...	...	...	...	...	1	...	...	...	...	3
Totals	311	52	61	7	23	7	11	16	3	43	75	1	12

homes whose fathers are located in the upper levels of occupation. This is characteristic also of every upper level occupation in which rulers are engaged.

As was shown previously, the occupations in which rulers engaged were almost entirely in the upper levels of employment. This is not true of their fathers, and there is upward movement to the extent that a difference exists between the two. The amount of climbing is shown in Table V.

TABLE V

TYPE AND PERCENTAGE OF OCCUPATIONAL CLIMBING OF RULERS AS COMPARED WITH THEIR FATHERS

Type of climbing	Per cent. of climbing			
	All rulers	Modern	Commoner	Colonial
Total climbing	25.7	24.4	30.6	13.9
Climbing from medium to high levels	23.1	21.4	27.5	13.9
Climbing from low to high levels	2.6	3.0	3.1	0.0

In a fraction less than 75 per cent. of the instances rulers have been born into homes located in the upper levels, where they have had the advantages of the purchasing power and prestige adhering to such levels. Over 23 per cent. of the climbing which has taken place has been of sons whose fathers were independent farmers. In less than 3 per cent. has the climbing been accomplished by rulers who were born into manual laborers' homes. In almost every instance the rise of sons has been the result of several factors which placed the sons in the élite of gainfully employed. In part it was the natural consequence of the apprentice system which prevailed in the professions and in business. In considerable measure it was an accompaniment of the settlement of the country. A pronounced factor has been formal schooling, which has equipped sons for occupational activity higher in social prestige and income than that in which their fathers engaged.

The popular notion persists that Presidents are representative of the common people. The total amount of climbing of Presidents as compared with their fathers has been 35.4 per cent., of which 3.2 per cent. represented climbing from low occupational positions of fathers to high levels of sons, and 32.2 per cent. was movement upward from farmer fathers' status to membership of sons in the upper occupational brackets. Since 1877 nine of the thirteen Presidents have had fathers in the élite of occupations. Only one President, Herbert Hoover, has risen during this period from the home of a laboring man.

CONCLUSIONS

Perhaps the greatest qualifying factor in the race for higher status has been formal education. This factor is more important to-day than ever before in our national history, for no longer does a young man enter the professions unless he has had college or university training. For the most part, the apprentice system is gone in the professions.

Education being basic to acquiring training required of national rulers, it becomes necessary to inquire whether educational opportunities are so equally open to all that no serious discrimination exists. In a recent analysis of the enrolments in colleges and universities the writer found that children of manual laborers comprised from 6 to 23 per cent. of the student bodies in these institutions, depending upon the type of school studied. Even such a popular institution as the junior college in enlightened California has a student body whose fathers in only 24 per cent. of the cases are engaged in skilled or unskilled

labor, whereas these occupations were being followed by 44 per cent. of the gainfully employed who had children of college age. All other forms of higher education are decidedly more aristocratic than junior colleges in the composition of their student bodies.[2]

It has been popularly argued that the laboring masses are relatively unproductive of superior intelligences, which accounts for their poor representation in our institutions of higher learning, and consequently their negligible number among our national rulers. When proportionate yields of the several occupational classes are determined on any intelligence test basis, this seems to be the case, but when total population numbers are considered, approximately 80 per cent. of those who test "very superior" and "superior" intellectually are found among the skilled, semiskilled and unskilled laborers, clerical workers and agricultural hands. Yet their opportunities to secure higher education and to reach higher occupations are relatively few.

Our national rulers, whom we might reasonably expect to be fairly representative of our people, are a highly selected group chosen from those who are born into moderate circumstanced or wealthy homes, who receive high educations and who enter the peak of occupations. The qualifying barriers are insurmountable for all except a very few of our people whom fortune has especially favored. In the interest of a democracy which seeks to use to the utmost the talents of all its citizens a more equitable plan should be devised which will enable talent, wherever it is born in the social scale, to express itself fully. But before any rational planning is possible the facts concerning vertical movement in all walks of life must be ascertained. It is only with the possession of these facts that a policy of correct occupational distribution can be formulated which will achieve equality of opportunity.

[2] H. Dewey Anderson, "Whose Children Attend Junior College?" *Junior College Journal*, January, 1934.

ART IN CLOCKMAKING AND WATCHMAKING

By Dr. D. W. HERING

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THE making of clocks and watches demands ability of two distinct orders, science and art. The need for the former is obvious and requires no demonstration. It is inherent, since a timepiece, even a poor one, will not function without the application of science in several forms, especially mathematics, astronomy and physics, and in a high-class instrument the scientific features are technical, ingenious and often abstruse. The part that art has played is important but is incidental rather than necessary. It may be of interest to see in what ways art has manifested itself in clocks and watches. In distinction from "The Arts," which comprise various industries whose products are generally the result of some mechanical process, and which are imitative or duplicative, the "Fine Arts" are supposed to depend primarily upon intellect and imagination; they are essentially creative and productive and are more fully entitled to be regarded as art.

Art in its grand forms—architecture, painting, sculpture, music—is so imposing that it overshadows the minor forms which find expression through various industries. So prosaic sometimes are the industries and so commonplace their products that the artistic highbrow looks with contempt upon these homely efforts and denies the right of their authors to rank with the élite possessors of the soul of art. However just or unjust such an assumption may be with respect to genius—that spirit which eludes definition—there is no denying the artistic quality of many an article of manufacture, whether textile, metal, jewelry or furniture; objects of design and construction that have often been so distinctive as to make their designers famous and their designs fashionable, creating "periods," although critics in one period condemn the taste that dominated another period. Conceivably a distinction might be drawn between a timekeeper and a work of art in that the primary purpose of the former is to be of practical service, while the latter, so far as its artistic quality is concerned, has no reference to practical utility; it is essentially esthetic or emotional in motif. That is not to say that a work of art may not be useful or that a clock or a watch may not have artistic features. Presumably the ingrained artist does practice art for art's sake, but even the Michelangelos were not indifferent to the pecuniary emoluments of their product, and literary genius has only too often been forced into the drudgery of producing pot-boilers. The clockmaker has always wanted his work to look attractive, whether he had sufficiently good taste to make it so or not.

An enthusiastic mechanical genius early in his life fixed upon clockmaking and watchmaking as embodying at once the principles both of science and art; science dealing with time and its mysteries and art that went beyond mere craftsmanship. Artists of the brush or chisel, of music or literature, have a lofty disdain for the pretensions to art by workers whose efforts depend upon machinery; but even if some of them are mere pretenders the work of others has often been fine and beautiful, and with the worst of them we may as well give the devil his due. An inspection of examples of the craft may show how far some are entitled to be called art and how far and in what ways others come

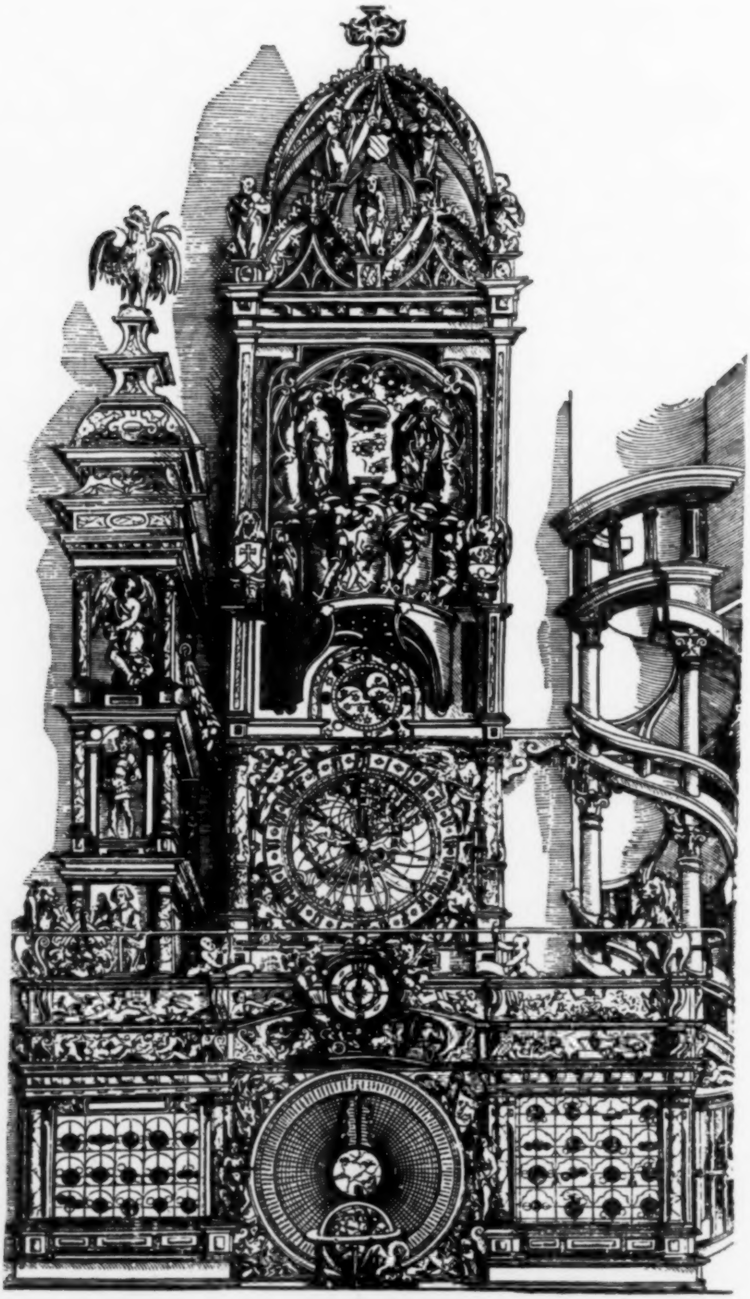

FIG. 1. THE SECOND CLOCK OF THE STRASBOURG CATHEDRAL, 1574

short. Recognizing first that the art of designing and making clocks may differ in some ways from that expended upon watches, the clocks themselves may be properly distinguished as public and domestic. The former were not said to be "made" or "constructed" but "erected" or "built," thus putting them in the class with buildings or monuments and making their art (if they had it) architectural. The term "fecit," often inscribed by makers, was generally reserved for domestic clocks. With these there seemed little opportunity for artistic effect, at least in the grand manner, although an authoritative critic, in a recent work, has commented pointedly upon the presence or the absence of artistic merit in them. While the individual clockmaker was still to be reckoned with, say especially from the middle of the eighteenth century to the middle of the nineteenth, English masters were in the lead, although the French, Swiss, German and Dutch had each their own definite style and American makers had begun to invade the field; and the same critic speaks severely of these last for the absence of art from their designs and, by implication, extols the presence of it in English output.

FIG. 2. ZIMMER TOWER AND CENTENARY CLOCK, LIERRE, BELGIUM
THE CLOCK OPERATES SEVENTY-THREE ASTRONOMIC AND CALENDAR DIALS. PHOTOGRAPH BY THE AUTHOR.

Early mechanical clocks were of massive construction; they were erected for a permanent stay in some tower, cathedral or town hall that was often of unquestionable architectural merit, and the

Fig. 3. Dial of the clock in the Palais de Justice, Paris. It bears the dates 1685, 1852 and 1909 when it has undergone reparation. Photograph by the author.

clock was designed to be in artistic harmony with the building, of which it was an important feature. In that character the clock of the Strasbourg cathedral, dating from 1354, has long been famous and has been the subject of much elaborate description and the cynosure of thousands of admirers. Sixty feet high and twenty-five feet wide at the base, it was an imposing structure and if the clock and the cathedral could be viewed apart from each other it would take no very critical eye to see that this clock belongs to that cathedral. It is perhaps the most bewritten of all clocks. Alfred Ungerer says ("Les Horologes Astronomiques"), "There have been published concerning this clock about four hundred works and descriptions more or less detailed, in prose, in verse, and in the form of working models ('*pièces de theâtre*')." Like most early public clocks this has been several times renewed and somewhat remodeled, but in the main has preserved its original form. The first clock operated from 1354 to about 1520; the second from 1574 to 1786; and the third from 1842 to the present time. During the intervening intervals of forty or fifty years it was too dilapidated for use. Fig. 1 shows the clock in its second and most elaborate form.

Hardly less celebrated is the great clock of Rouen, dating from 1389. The Strasbourg Cathedral clock is noted for its automata, like that of St. Sebaldus in Nuremberg, that of Berne, and many others; the Rouen clock especially for its beauty of design and decoration. With the revival of learning following the Renaissance the clock came to be re-

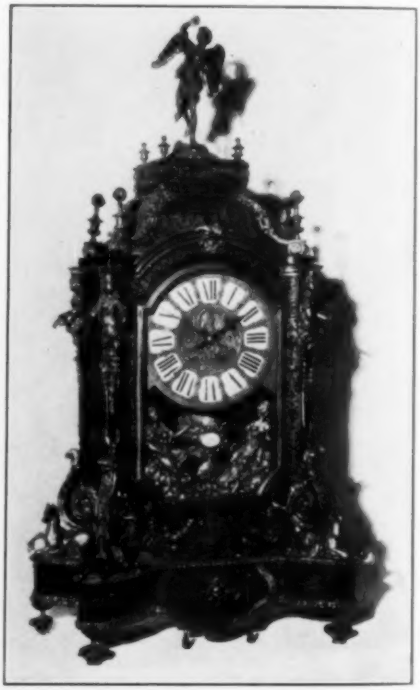

Fig. 4. Louis XIV clock by Baltazar, about 1700. This timepiece as well as those shown in Figs. 5–7 and 9–18 form part of the James Arthur collection of clocks and watches at New York University.

garded as an important part of municipal equipment and a source of pride to the citizens, and civic spirit impelled the different cities to vie with one another in the effort to produce the finest example. Mr. G. H. Baillie, a most competent authority on this subject, enumerates 223 public clocks erected prior to 1600—ninety-three in the fourteenth century, sixty-five in the fifteenth, and seventy-five in the sixteenth; and these were succeeded by many more in the seventeenth and eighteenth centuries. Practically every city of any considerable size in Europe had one and some had several. They were usually placed upon the City Hall or in cathedral spires or towers, where they could be seen and heard at a great distance.

As a rule the movement of a public clock is mounted on a substantial frame within the building and only the dial is

FIG. 5. DUTCH HOOD CLOCK, ABOUT 1700.

FIG. 6. CLOCK IN EMPIRE STYLE, FIRST QUARTER OF THE 19TH CENTURY.

open to view; it is upon the dial, in such cases, that ornamentation is lavished. One of the most celebrated of clocks was that built for King Charles V of France by Henry De Vick, 1370–1378. This was placed in the Palais de Justice in Paris. The original clock-work has entirely disappeared, but the dial, several times renewed, is still in place on the eastern façade of the Palais de Justice at the northeastern corner. Its present appearance, with overhanging foliage, is shown in Fig. 3. The dial ring is five feet in diameter; the extreme height of the dial is nearly twenty feet and width about twelve feet.

Marking the time of day is only a small part of the duty of an astronomical clock; some are intricate and multitudinous in their performances and show many astronomical positions, move-

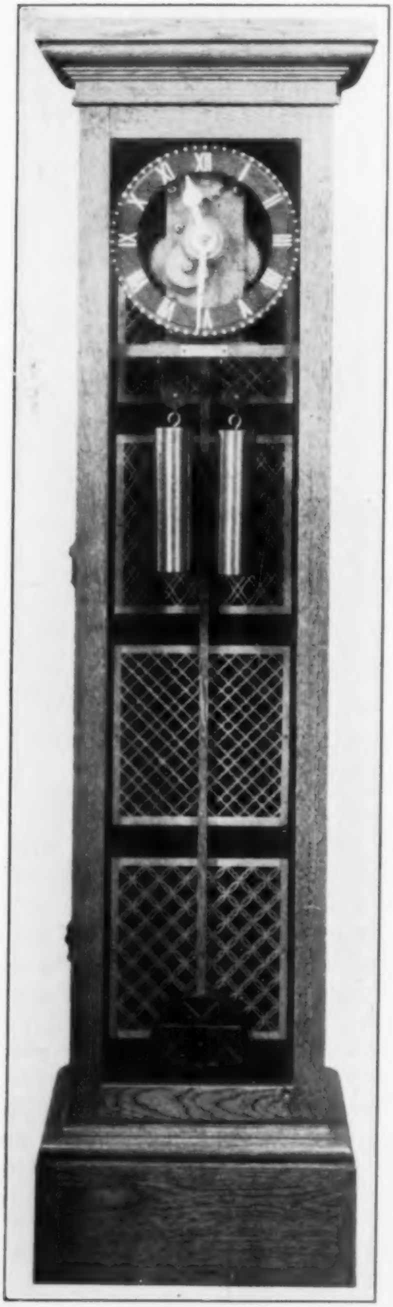

FIG. 7. LONG CASE CLOCK BY JAMES ARTHUR, 1902.

ments and phenomena; the position of the sun (or the earth) in the zodiac, the change of seasons, the phases of the moon, the day of the week or of the month, and many other features, each of which had its own separate dial; and for each dial there was apt to be a costume appropriate to the phenomenon—sometimes allegorical sculpturing—calling for an attempt at artistic treatment. The hour circle is usually divided into twenty-four parts (or hours), which are numbered from one to twenty-four, or in two successive series of one to twelve.

This multiplicity of dials and complexity of operation reached a climax in 1930, when Alfred Zimmer, of Lierre, Belgium, clockmaker to the Royal Court of Belgium, completed a "Centenary Clock" which he donated in 1931 to the city of Lierre on the occasion of the hundredth anniversary of Belgium's independence. The elaborate timepiece was supplemented by numerous movements constituting an "Astronomic Studio," and the combination was installed in a three-story stone tower reconstructed by the city for that purpose. The principal dial consists of a large central circle showing Greenwich standard time; this is encircled by twelve other dials, each of which indicates some feature of astronomy or the calendar. In all there are seventy-three dials. A replica is to be exhibited at the coming World's Exposition to be given in Brussels in 1935.

Naturally tower clocks do not find their way into private collections, but their merits as also their defects are matters of record. They are still in demand, but as they are not objects of mass production each one is built by special contract with a "company." The hands traverse the dial and the hours or chimes are rung by electric motors controlled from a master clock in a lower room of the building. Science

governs their action and their design, and art plays a subordinate rôle. The clock of the Colgate Company, in Jersey City, has the largest dial in the world, sixty-one feet in diameter, and has many exceptional features, but no one could accuse it of being architecturally beautiful. That on the Paramount Building in New York City is more pleasing to the eye and would probably be more approved as an example of art.

With clocks (not watches) it is almost exclusively the case or mounting that is the subject of artistic treatment, and this was often, perhaps most frequently, the work of a designer whose name has been lost, while that of the maker of the mechanism, which is the clock proper, has survived. They were not usually the same person and sometimes were so completely dissociated that portable clocks at first were often supplied without a case. This, if desired, was made by a cabinet maker, often in a locality remote from that in which the original clock was made and at a later or, possibly, an earlier date. To this custom, however, there were important exceptions. Royalty had "makers to the King," who enjoyed royal patronage in various lines and supposedly derived advantage in business from the right to affix such title to their names. A clockmaker and a cabinetmaker "to the King" were among those who were thus favored. Technically, clock cases are furniture, and as furniture went in fashions or "periods" the clock cases followed the fashion and what was highly approved in one period was not acceptable in another, unless there was a revival. Specimens of an earlier period came to be valued later as antiques. A notable example of this was the so-called "Buhl work." André Charles Boulle (1642–1732), cabinet maker to the king under Louis XIV, introduced a very ornate style in which the body of a piece of furniture was veneered with a layer of tortoise shell that was inlaid with metal or mother of pearl cut out in elaborate patterns. It was costly but became exceedingly popu-

Courtesy of Dr. N. B. Van Etten, New York.
FIG. 8. BANJO CLOCK, ABOUT 1825.

lar with persons of wealth or the nobility. It was taken up in other countries than France and the name was Germanized into "Buhl," which is the form now

most generally used. Though now out of vogue, specimens are to be found in museums and are highly prized. A good example is shown in Fig. 4. This clock was made about 1700 by Baltazar of Paris, who was clockmaker to the king.

In his satirical poem on "Contentment" Oliver Wendell Holmes wrote:

Wealth's wasteful tricks I will not learn,
Nor ape the glittering upstart fool:—
Shall not carved tables serve my turn;
But all must be of buhl?

The taste for the *rococo* which prevailed in France in the late seventeenth and early eighteenth centuries was reflected in the work of other countries. In Holland especially, stimulated by the ingenuity of the great physicist Christian Huygens, clock-making became prominent. Their most admired clocks of this period were florid displays of gold and color. Fig. 5 shows an example of their "hood" clocks having

FIG. 9. ACORN CLOCK, ABOUT 1825.

an ornamental case under a decorative canopy.

The styles of Louis XIV, Louis XV and Louis XVI (1643–1793) were florid, in a steady decrescendo until, during the Empire (1804–1815), they became much simpler; using, in costumes, the flowing lines and graceful curves of classical Grecian drapery, furniture became severely simple in design and clocks followed the new fashion unless designed by an independent and unconventional thinker. Fig. 6 is a clock in Empire style contrasting with the Louis XIV of Fig. 4.

The late Mr. James Arthur, of Brooklyn, N. Y., in the course of more than forty years gathered a large and varied collection of clocks and watches from many different countries and of dates covering a period of three hundred years. He was not a professional clockmaker or watchmaker, but he was a skilful mechanic and an enthusiastic inventor. He constructed numerous clocks of his own design, among them several illustrated by Fig. 7. This, in the natural color of the wood, with straight lines has for its only ornamentation the fretwork lining the back which, with the mechanism, is plainly in view through the glass front and sides of the case. Lacking altogether the elegant marquetry of Boulle, and the gaudy and "baroque" carving of the Dutch and Friesland clocks, it is given here as an extreme contrast to those shown in Figs. 4 and 5, and in its proportions and good taste is more artistic, notwithstanding the fact that the major purpose of its maker was to show special features of the clock as a time-keeping machine.

A handsome volume which appeared recently, recounting Connecticut clockmakers of the eighteenth century with numerous illustrations of their clocks, drew comments from an English authority disparaging to the American efforts on account of their commonplace designs and ungraceful proportions. Within a

quarter of the succeeding century, however, *i.e.*, between 1825 and 1850, the making of clocks in America had grown into a great industry, and competing inventors and manufacurers were put to it to devise cases that would have some distinctive form or character. Among the best known and most popular forms were the "Banjo" by the Willards (Simon and Aaron) of Massachusetts, the "Pillar and Scroll Top" by Eli Terry, the "Looking-glass Case" by Chauncey Jerome, and the "Acorn" by the Forestville Manufacturing Company; the three last named were produced in Connecticut. The Banjo and Acorn are shown in Figs. 8 and 9.

Simon Willard patented his "improved timepiece" (banjo) in 1802; it was meant to be hung up against a wall or pillar. There would seem to be no particular reason why a clock should be shaped like a banjo, but a reasonably close-fitting round head was suitable to contain the movement; for the slender swinging pendulum no enclosure could be more appropriate than the tapering waist; and the pendulum bob, three or four inches in diameter and requiring a path six or eight inches in length, naturally suggested the horizontal box below. The inventor probably had no intention to copy a banjo for the design of his clock, but the semblance of that instrument into which the construction grew no doubt tickled his fancy—as it did that of his customers. Professor W. I. Milham in "Time and Timekeepers" says that the Willards never used the name "banjo" for these clocks.

The Terry clock, patented in 1814, was born of the desire for a clock with a wooden case to stand upon a shelf instead of to hang up against a wall, and the style adopted by Eli Terry met that purpose in the simplest possible form and gained immediate popularity.

But why should a clock be made to look like an acorn? Unintentionally

FIG. 10. SMALL CLOCK WITH CONICAL PENDULUM AND CYLINDRICAL ROTATING DIAL.

perhaps the realm of musical instruments had been invaded by Simon Willard with a startling popularity as a result; then the cabinet form of case had been appropriated by Eli Terry and modified by Chauncey Jerome by the insertion of a looking-glass; what remained for competitors better than the natural product of a forest tree? Competition became a free-for-all contest of gladiators in the arena: Simon Willard dealt his rivals a severe blow with the banjo: Eli Terry countered with the pillar and scroll top case; Chauncey Jerome came in with a looking-glass;

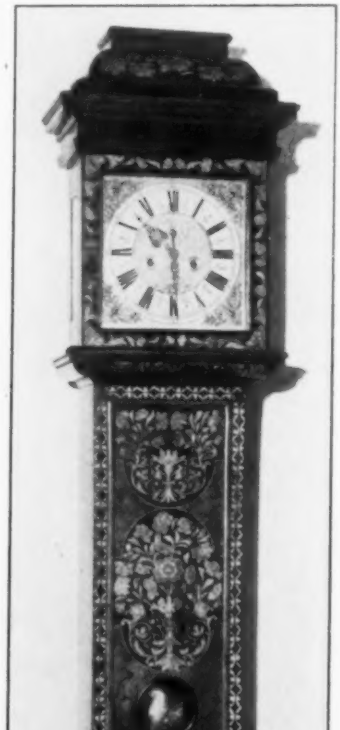

FIG. 11. CLOCK CASE OF WALNUT, INLAID WITH WHITE WOOD AND EBONY, 1695.

the Forestville Manufacturing Company bombarded them with acorns; and all these designs were pirated by other makers. Among early American clockmakers there was none too much regard for rights of priority, and plagiarism was sometimes pretty high handed. These clocks were all good timepieces for their day and with their methods and material of construction, but as works of fine art not to be taken very seriously.

It should go without saying that a structure should accord in design and appearance with the purpose it is to serve. That is an end to be desired, but one which architects do not always succeed in attaining, and we have imposing libraries that look like mausoleums or the Pantheon and are ill adapted to the needs of readers, students and librarians; theaters that suggest churches or picture galleries; and railroad passenger stations that look grand but confuse and impede rather than help the traveler or simplify his perplexities; and the same discord is found in many public clocks. Unless the clock is part of a cathedral it is hard to see why it should look like one, yet that was a favorite pattern with early clockmakers. It was carried to extremes in what is regarded by some competent judges to be the oldest clock now in existence, that of Philip the Good, Duke of Burgundy, accounted as of about 1430. The most plausible inference is that the maker devoted his efforts to producing a work of art and dismissed the idea of utility as something not to be included in an artistic conception. Its timekeeping quality was less important to him than the artistic.

The small clock shown in Fig. 10, only seven inches in height, immediately calls to mind the beautiful little Temple of Diana in the gardens of the Villa Borghese, Rome.

Considering the distortions and mon-

strosities that are often displayed in so-called art exhibitions it is hardly worth while to hold the clockmaker strictly to account if he departs from its canons.

In the Middle Ages and up to within a century ago the interests of tradesmen both in commerce and manufactures were subject to regulations of "guilds" which were organized for many occupations. Before any guild of clockmakers or watchmakers existed the scattered mechanics who made or built clocks were metal workers and were most often members of a blacksmiths' guild. Sometimes they were expert blacksmiths to whom clockmaking was an avocation rather than a vocation. In Scotland metal workers were incorporated in various guilds as "hammermen," that of Edinburgh dating from 1483, but clockmakers and watchmakers were not admitted to membership until 1646. The idea of taking a watch or a clock to a blacksmith to be repaired seems fantastic to us now and we do not think of a smith of any kind as an artist, but our estimate calls for some revision when we recollect that Quentin Matsys, a renowned painter, first arose to fame by his artistry in ironwork. Still, Quentin Matsys are not numerous. Incidentally, it is interesting to note that such masters as Quentin Matsys and Albrecht Dürer were given to mathematical formalism that would be repudiated by freehand painters. The former fairly geometrized his subjects by arranging them in a scheme of mathematical lines and figures, and the latter followed a precise system of proportions—an anthropometric formula—to depict character or temperament in his men and women; and so did Charles Le Brun, court painter to King Louis XIV, and probably many others.

It is upon domestic rather than upon public clocks that art has been called into service. The long case ("Grandfather Clock") has been made the sub-

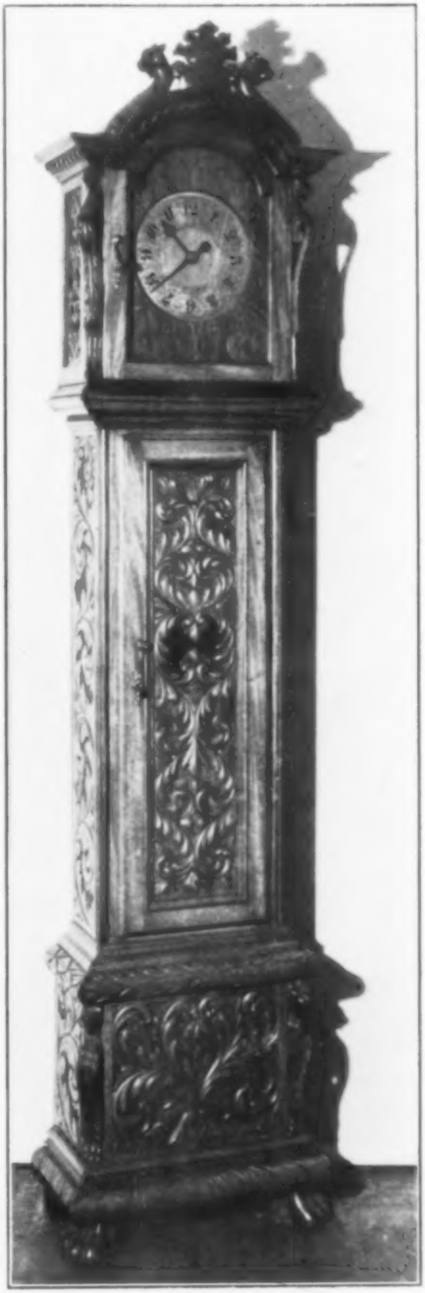

FIG. 12. CLOCK CASE OF MAHOGANY, RICHLY CARVED, MODERN.

FIG. 13. BRONZE CLOCK BY JAPY FRÈRES, ABOUT 1810.

ject of decoration especially by inlay work, as in Fig. 11 or by wood carving as in Fig. 12.

Before hand work was displaced by machines, designs could be varied without seriously affecting the cost of production. The greatest variation then meant a change of style, while minor changes could be made in individual pieces. At one time it was the fashion to mount the clock upon some animal, the elephant being the favorite; again the clock cases, especially small ones, often of marble, onyx or alabaster, were surmounted or flanked by sculptured figures of cupids or mythological creatures or statuettes of bronze or brass. Fig. 14 shows a handsome French modern clock on a mahogany base. The metal mounting is reddish brass, highly ornate, with portions of its surface finished in colored enamel. The pendulum, a Cupid, swings forward and back instead of right and left.

In the making of metal cases Frederic Japy of Beaumont began the departure from art for its own sake, with watches in 1776 and with clocks in 1810, by an innovation in their manufacture which might be characterized either as standardization, commercialization or degradation, but which grew out of artistic capabilities in the introducer. This was the use of machines to manufacture in large numbers cases of clocks or watches from his original *ébauches*—a sort of mass production of cases that were alike in the rough, but which were to be finished by hand and in which there was enough leeway for modification of the design to give a separate individuality to each one. Fig. 13 is an example. As much as a hundred years ago the dispute raged between the disciple of art and the philistine as to whether the spiritual perversion is not more than justified by the material benefit to society.

About the year 1600 A. D. the Japanese began to use mechanical clocks for keeping time according to their system of horology, which they had borrowed from the Chinese many years earlier and which differed in many respects from

FIG. 14. ORNATE FRENCH CLOCK, MODERN.

that of western peoples. The Japanese retained this system until 1873, and during the period from 1600 to that date, nearly three centuries, they used clocks which they adapted to their peculiar method of time reckoning. They were great copyists and they copied the mechanical construction and lantern form of early Dutch clocks, but the style, coloring and finish reflected the oriental tone of art. It was the custom of Japanese artisans to dwell upon minutiae of detail. Moreover, whether a part of the construction was to be conspicuous or not, it had to be ornamented like all the rest. In Fig. 15 the brass case on the pyramidal base contains the mechanism which is like that of the European "foliot" clocks of the sixteenth century. Elaborate engraving covers this entire case and is supposed to be pleasing to the eye. The weights are hidden within the wooden base and are visible only when this is open, as in the illustration, but these weights, particularly the dumb-bell, are covered with the same profusion of carved tracery. In some of their earliest clocks the case of iron is inlaid with beautiful designs in silver and copper—the damascening of the armorer's art in the Middle Ages. The clock here shown is five feet high, including a hood. To the Japanese, short in stature and, when not standing, seated on the floor, this was a "tall" clock.

It is when an industry is in process of development that attempts are made to cater to popular taste and also to educate it, as seen strikingly during the last half century or less in the progress of electrical invention, the automobile and radio; and in a machine age it is in such lines of growth that budding artistic skill comes into flower; attractive designs are constantly in demand and the demands become more exacting with every advance. Students in art schools or schools of design, ambitious of achieving some great work eventually, seek opportunity to apply their talent by designing models of cars, furniture, household appliances, patterns for wall papers or for textiles, or what not, in the employ of manufacturing companies before they attain the dignity of an atelier of their own, or solicit and fill private or public commissions. Manufacturers of clocks and watches are on the alert for fine designs of cases as well as for improvement in the movements. An agent so potent, so adaptable and all-in-

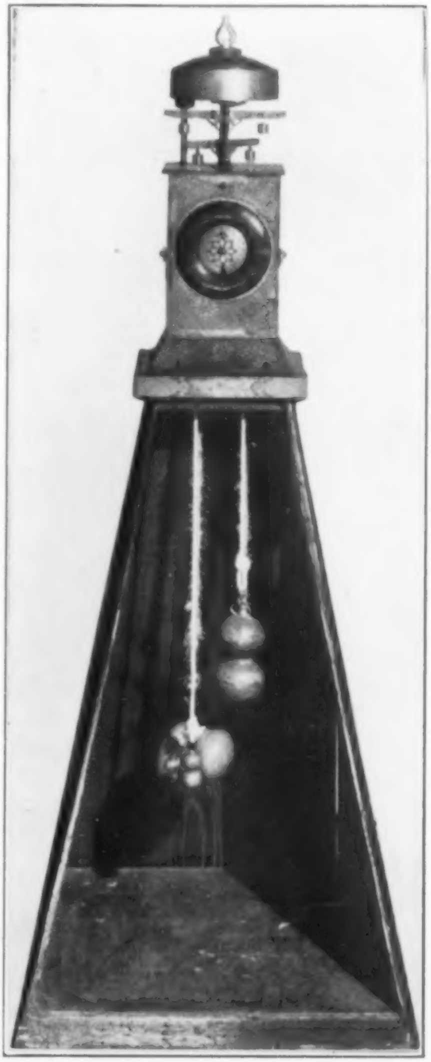

FIG. 15. JAPANESE CLOCK ON PYRAMIDAL BASE.

sinuating as electricity was certain to be enlisted in clockmaking, and although electric clocks have been produced for many years they had not very encouraging success before the general distribution of electricity from central stations opened the way for better electric clocks. Within the last few years two types have been rapidly developed: one, an electrically controlled "balance" clock; the other, the "telechron" or synchronized alternate current motor. The idea caught the public fancy, and the simplicity of the mechanism, especially of the latter form, made it possible to construct them cheaply. As a consequence, competition was keener to obtain fine designs of mounting than to make a fine piece of machinery. Unfortunately, there are companies operating that are less concerned about producing a real work of art than about making something bizarre in appearance yet cheap enough to be within the reach of every family, and the country is deluged with millions of trashy clocks, made to sell. The purchaser has a choice of many different models, the display room is gaudy, and if the clock will only go over the salesman's counter it doesn't matter much about its going afterwards. A prospectus of a prominent manufacturing company, making good clocks, recently showed about a dozen forms of small electric clocks, most of them odd in shape or color, one like a tombstone, and none noticeably artistic. But, with all the chaff there is a fair admixture of good grain. One leading company lays stress upon the fact that their models are "spirited designs from Europe's foremost casemakers," and they are unquestionably handsome. Some are revivals of early designs and if any rank among artists may be accorded to Thomas Chippendale, George Heppelwhite, Thomas Sheraton, Duncan Phyfe and others who produced distinctive furniture, many modern clocks may be considered artistic, since their makers used (or abused) the styles of these masters.

FIG. 16. WATCH WITH PAINTED ENAMEL BACK, ENCIRCLED WITH BRILLIANTS. BY JULIEN LE ROY, ABOUT 1730.

Passing from the artistry of the clock to that of the watch is in some sense like passing from the grand canvasses of Paul Veronese or Tintoretto or the murals of Puvis de Chavannes or Blashfield, La Farge, Abbey or Sargent to the exquisite gems of Hans Memling or the warm delicacy of a Claude Lorraine. (The Post Office Department did not shrink from the attempt to put the Grand Canyon on a postage stamp!) And whereas in clocks artistic feeling found expression in forms appropriate to furniture, in watches it necessarily took on the character of jewelry, since the purpose of a watch, other than to keep time, was to adorn the person of its wearer. This was more markedly so in early watches, which were worn as much for decorative effect as for telling the time; so the art here was that of the goldsmith instead of the cabinet maker. The work of the goldsmith, silversmith and jeweler is among the oldest examples of art and is still recognized as art, but the manufacture of watches, like that of clocks, has become subordinate to that of

the artisan except in the finest specimens. It was different before individualism was submerged under mass production. For everyday purposes the utilitarian does outweigh the artistic.

A rota of distinguished clockmakers and watchmakers would include names as familiar to artisans of that craft and their patrons as the best known among painters, sculptors, musicians or any other class of creative genius. If a seventeenth-century Dutch citizen alluded to his "Frans Hals" there was no need to explain that he meant a painting; if an Englishman of the same period alluded to his "Tompion" he was as readily understood to mean his watch—equally a masterpiece of art; and the claim of such makers to the rank of artist rests upon the facts that they were creative and that their work was often intellectual more than manual, since it involved a good deal of horological science.

One of the most celebrated collectors of watches, Carl Marfels, acquired several collections in succession. The first and second of these collections became the property of the late J. Pierpont Morgan; the third was Mr. Marfels's crowning achievement. It consisted of only twelve watches, but these were of the most exquisite character, and the most important criteria in gauging the merit of the pieces were: (1) artistic quality; (2) unimpaired state of preservation; (3) rarity of the objects. Note that "artistic quality" is put first. In a beautifully illustrated description of the third collection by M. Loeske, as originally printed in the *Deutsche Uhrmacher-Zeitung*, concerning "the artistic treatment of cases, dials and cocks" the writer says, "it is indeed not saying too much that this artistic treatment . . . can not be surpassed . . . these old masters of their art will as little ever be surpassed as the great Greek sculptors, of the great painters of the 16th and

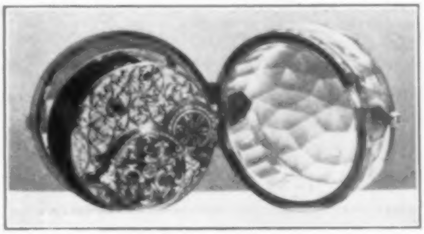

FIG. 17. RARE WATCH IN CRYSTAL CASE, SEVENTEENTH CENTURY.

17th centuries, the architects of the Renaissance, or the old classic musical composers." Further, he says, "it is much to be regretted that of all the remarkable watches we find in our museums and private collections, only the name of the master who has made the watch work may still be known, but very seldom that of the goldsmith who has created the highly artistic and concerning the value of the object the much more important case.

Opportunity for developing artistic ideas is necessarily limited in an object so small as a watch; nevertheless, the ideas were developed with considerable variety, and both skill and taste were expended not only upon the watch cases and dials but also upon the framework

FIG. 18. REPEATING WATCH WITH GOLD *repoussée*; CASE BY QUARE.

that supported the wheels. At first the watch was altogether metal work and was decorated by carving or engraving; from an earlier period painting on enamel was carried to a high stage of excellence, and artists in that line rose to eminence; about 1635 enamel dials began to be used on watches, and this style of art was carried over to the finish of watches, both face and back. As its beauty depends on the coloring it can not be satisfactorily shown in a black and white picture. Their elegance was sometimes enhanced by a setting of precious stones, and fine specimens of that art, rivalling the artistic claims of other paintings, now command thousands of dollars. This mode of decoration continued, but with gradual decadence, through the eighteenth century.

Styles come and go in jewelry as they do in furniture and just as designs of clocks varied with styles of furniture, so taste in watches varied with that in jewelry. The better grade of work has usually been in gold and silver; in later years platinum has figured somewhat, though not largely, and gold and precious stones have generally been used most effectively. Before the watch was so cheapened that everybody could have one a fine specimen was a luxury that appealed to the vanity of the wearer. It became a *sine qua non* in fashionable circles, and an "exquisite" among dandies was not content with mere gold. The watch was suspended from a chatelaine, and both were richly bejeweled, but even that was not enough for insatiate vanity, and in the latter part of the sixteenth century the work of the goldsmith was further beautified by that of the lapidary, and watch cases were made of single crystals of quartz. Clear and highly polished they rivaled even the diamond in beauty. Fig. 17 shows a fine specimen.

The watch in Fig. 17 has a crystal case that is a round, deep cup with a lid, also of rock crystal. The pendant knob and ring are of gold, and the lid is held on by a gold band. The entire case, including the lid, is smooth on the inside but finished on the outer surface with polished triangular facets, more than two hundred and fifty in number. The movement, finished largely in gold, is no less artistic. Through the transparent case is seen the entire movement, richly decorated in gold—the realization of a watchmaker's dream. It is by J. Mercier, of Paris, about 1695. This style of watch was especially favored in France and Germany during the seventeenth century. In another style of decoration, *repoussée,* the case was stamped from within, producing in relief a pattern of sculpture or a copy of some painting. It is illustrated in Fig. 18.

Watches as well as clocks often take the form of oddities sometimes grotesque, not always pleasing (as, for example, a skull or some distorted figure), and often lacking esthetic features that might entitle them to be regarded as fine art. In the world war the watch was called into service as never before in military operations, and the practise of wearing it on the wrist became common. The same practise was taken up by civilians and the *beau monde* soon called for patterns of taste and beauty, so the wrist watch has been produced in styles both grotesque and arabesque.

The scientific character of the watch has been developed more than the artistic, but at no time has a maker of first rank or a company producing first-class timepieces failed to employ high artistic ability to provide suitable cases in which to mount the movements; and few industrial arts employ as great diversity of talent as does the making of clocks and watches, where subjects range from large structures of stone or wood, through intermediate sizes and forms, to miniatures and gems.

THE NATURE OF CANCER

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CANCER, like life, still baffles the scientist who searches for the deeper secrets of its nature. Perhaps this is because cancer is very definitely a form of life. But to say that we know nothing of the nature of cancer is to take too pessimistic a view. When the isolated known facts concerning this disease are brought together they not only form a surprisingly large mass, but when pieced together they form a remarkably complete pattern from which one may judge its nature with some degree of accuracy.

Cancer is not now believed to be the result of infection with any known *type* of microorganism. The reasons for this belief are numerous. Every known type of microorganism — filterable viruses, bacteria, yeasts, fungi, protozoa and even metazoa—have been charged with the crime of inducing cancer. But no single species of parasite has been isolated from cancer with any degree of constancy; and none of those which have been isolated have unquestionably induced well-authenticated cancer. The only exceptions to the last statement are the filterable virus of chicken sarcoma and the infectious genital "sarcoma" of dogs. But these are strictly limited to the respective species of animal.

All infectious diseases have a period of incubation during which the invading microorganism is increasing to sufficient numbers in the body to induce symptoms. It is true that in some chronic infectious diseases, such as tuberculosis and leprosy, the incubation period is not clearly recognizable. In cancer no incubation period exists in the sense in which it was defined above. In experimental tar cancer, and probably also in spontaneous cancer, there is a relatively long latent period. But this delay in development of the disease is not due to the slow growth of any microorganism in the body. Furthermore most of the agents which will induce experimental cancer—such as tar, arsenic, shale oil, soot — have more or less germicidal power.

In infectious diseases some degree of immunity develops and can be demonstrated by the presence of immune bodies in the serum. No such immunity to cancer has been demonstrated. It is even claimed by Freund and Kaminer that normal human serum will cause the lysis of human cancer cells, while serum from a cancer patient will not.

Cancer does not behave like an infectious disease. When pathogenic microorganisms enter the tissues of the body many types of cells—polymorphonuclear leucocytes, lymphocytes, plasma cells, histiocytes, capillary endothelium and fibroblasts—take part in the processes of resistance to the invasion of the microorganisms and the repair of the damage which they do. In cancer one type of cell not only predominates, but the connective tissue stroma and blood vessels within the tumor merely furnish passive support or nutrition to the dominant cells. Neither the tissues in which the cancer is growing nor the body as a whole offers any effective resistance to the growth of the cancer.

If cancer is not an infectious disease, two corollaries naturally follow. First, cancer is not transmissible. There is no danger of a healthy person's "catching"

the disease, no matter how closely he may be associated with the patient. Second, there is no stigma or disgrace attached to cancer. It is not a "blood disease" in the sense in which that term is used by laymen. The feeling of shame which many cancer patients have is one of the most serious obstacles in the way of successful treatment of the disease, for it leads to delay and delay is fatal.

Even the layman recognizes that cancer is a growth. But growth is a normal attribute of living tissues. To appreciate the peculiarities and to understand the nature of cancerous growth it is necessary to contrast it with normal growth as it occurs in the developing embryo and in the regeneration and repair of injured tissues.

Every human being begins life as a single cell, the fertilized ovum. This cell divides into two, these into four, and this process of cell division at first proceeds at a rate that no cancer can equal. This rapid multiplication of cells proceeds in an orderly fashion and develops a definite pattern. The particular pattern developed is the result of many factors.

(1) *Heredity*. Each species of animal has its own pattern of growth. In the development of the human embryo certain faults in reproducing the normal pattern may occur. Some of these faults, such as Cohnheim's embryonic rests, may be a factor in the later occurrence of cancer.

(2) *Orientation*. Very early in the process of growth the mass of cells, possibly the original fertilized ovum, becomes orientated with reference to itself into cephalad and caudad, anterior and posterior, the right and left, parts.

(3) *Formation of embryonic layers*. With the infolding of the hollow sphere of cells the ectoderm, entoderm, and mesoderm originate.

(4) *Differentiation*. From these several embryonic layers the various organs of the body differentiate in accordance with the special pattern of the species.

(5) *Subordination of the organs*. The size of each organ is subordinated to the size and needs of the organism as a whole. No organ exceeds its allotted volume.

(6) *Transference of energy of growth into energy of function*. In its earlier stages the chief need of the embryo is the development of its organs with their potentialities of later function. As these organs approach or reach their requisite size the rate of growth slows down. The enormous energy previously used up in growth is now available for the performance of function.

Throughout normal embryonic growth the enormous rate of increase in the number of cells remains within the limits of its special pattern. The rate of growth gradually decelerates until at birth it is proceeding at a leisurely pace, which is progressively retarded after birth until it ceases or at least becomes balanced with the loss of cells due to wear and tear, when the individual reaches his full stature.

The transference of energy of growth into energy of function is not an irreversible change. When tissue is destroyed, the adjacent cells regain their power of regeneration in inverse proportion to their degree of differentiation and specialization. These cells revert to a more embryonic type but still maintain the quality of obedience to the law of growth observed by embryonic cells in general. Since the connective tissues are the least differentiated, they take the dominant rôle in repair with the ultimate production of scar tissue. But in the process of repair the growing cells reproduce the patterns of their respective tissues; keep within the limits of the needs of the occasion; do not invade healthy surrounding tissues, nor produce metastases; do not exceed the

amount necessary to adequate replacement of the cells originally destroyed; progressively diminish their rate of growth as the goal of complete repair is approached; and cease to regenerate once the destroyed tissue has been replaced and the damage repaired. The growth of repair is not continuous, and the newly formed cells differentiate and mature. Occasionally the production of scar tissue may be too luxuriant, giving rise to the keloid not infrequently seen in the Negro race. If the process of repair occurs in a region which is also the seat of chronic inflammation, any epithelium which is involved may undergo such marked hyperplasia and even metaplasia as to resemble a malignant growth. But when the inflammation subsides, the epithelial hyperplasia and metaplasia cease and most of the excess proliferated epithelium disappears or becomes walled off by connective tissue.

Cancer begins in one place from a single cell or from a small group of cells. In its early stages it is, therefore, a local disease. But the growth of cancer cells differs in almost every respect from the normal growth of cells in the developing embryo and in the process of regeneration and repair. Although the cancer cell is derived from the cells of the body it is quite unlike any other cell of the body in any stage of its development. Cancer cells have undergone dedifferentiation, but they have not become embryonic cells. Their rate of growth is essentially continuous without the normal retardation as some goal is approached, for they have no goal; they do not reproduce any pattern, or do so only imperfectly; their growth is not oriented, but proceeds irregularly in all directions; they acquire a new habit of growth, become autonomous and are not controlled by the law of the needs of the body as a whole; they force their way into surrounding healthy tissues and destroy them; they invade blood and lymph vessels and are carried to distant parts of the body where they form new foci of cancer growth; their energy of growth is never transformed into the energy of function, because they perform no useful purpose in the body; they acquire a new habit of respiration, anaerobic glycolysis, and produce large quantities of lactic acid even in the presence of an abundant supply of oxygen, a process which neither embryonic nor adult or mature cells exhibit when the supply of oxygen is adequate. These characteristics mark the cancer cells as something quite different from any normal cells of the body at any stage of its development.

What causes this deep-seated, fundamental change in one or more normal cells of the body to transform them from useful units in the economy of the body into the racketeering elements that they become, is unknown. Neither do we know what causes the original fertilized ovum to proliferate at such an amazing rate. But to say that nothing is known concerning the cause of cancer is untrue. Quite enough is known concerning the agencies and influences that will induce cancer to justify efforts directed toward its prevention. The present status of the cancer problem can best be introduced by a brief historical survey of our knowledge of this disease.

Cancer is a very old disease. Fossil remains of dinosaurs and of pithecanthropus erectus show evidence of tumors of bone. The Ebers papyrus (1500 B. C.) has a section on tumors. Even in the days of Hippocrates patients placed votive statuettes in the temples in the hope of being cured of disease and at least one such clay model of an ulcerating carcinoma of the breast is still in existence. Physicians have therefore recognized cancer for more than 3,000 years. But it was not until the invention of the microscope and espe-

cially the discovery of a method of sectioning and staining tissues that the true nature of cancer was revealed and a means provided for its accurate differentiation from other diseases which resemble it in gross appearance.

The first phase of the development of modern knowledge of cancer—its microscopic diagnosis—began with Virchow. This advance added relatively little to the fundamental problem of the etiology and essential nature of cancer, but the method still has everyday practical application in every accredited hospital. The limitations of this method were soon recognized and scientists turned from this narrow field of observation to the broader and more stimulating but treacherous field of theory. The last third of the nineteenth century saw the birth of Cohnheim's theory of embryonic rests, of Weigert's theory of tissue balance and numerous other attempts to solve the problem merely by "giving thought" to it—a method which has not added one cubit to stature of our knowledge of cancer.

A new impetus was given to the study of cancer when Jensen, in 1903, reported the transplantation of a tumor from one rat to another and described adequately the conditions essential to successful transplantation. The yield in knowledge from this procedure was disappointing. The chief contributions from this source were: (1) that it is the transplanted tumor cells that grow in the host animal; (2) that the tissues of the host take no part in the growth except to furnish a supporting framework or stroma; (3) that some animals possess a high degree of resistance to transplanted cancer which is unable to grow in them; (4) that the presence of one growing transplanted tumor renders the animal immune to a second transplantation of the same tumor; and (5) that transplanted tumors do not ordinarily metastasize but may be made to do so by massage and other rough handling.

Before the depression due to disappointment with the yield of knowledge from Jensen's contribution had reached serious proportions, Fibiger reported the finding of carcinoma in the stomach of a rat infested with a nematode worm. Learning that the larvae from this parasite occurred in cockroaches he searched for months through the City of Copenhagen for these vermin infested with the desired nematode larvae. He finally found an abundant supply in an old sugar mill in the outskirts of the city, only to have the mill burn down immediately thereafter. But this method of experimental production was too uncertain and was soon replaced by a more reliable and simple method.

About the middle of the nineteenth century, Virchow had insisted that chronic irritation was an important factor in the causation of carcinoma. By 1914, numerous types of occupational cancer were known to follow prolonged, relatively mild irritation by chemical and physical agents; such as, "chimney sweep's cancer," due to irritating effect of soot collected in the folds of the skin of the scrotum; cancer of the lung in the workers in the cobalt mines of Schneeberg, Germany; "mule spinner's cancer," due to the action of lubricating oils on the skin; cancer among shale workers, probably due to paraffine; cancer of the bladder in aniline workers; cancer developing in chronic ulcers of the skin among the early workers with x-rays; cancer of the cheek in chewers of the betel nut; and "Kangre cancer" on the front of the abdomen of inhabitants of the Vale of Cashmere, who carry a small stove in a wicker basket under their garments.

In 1914 Yamagiwa and Itchikawa described a reliable and effective means of producing cancer experimentally by the simple procedure of painting the skin of an animal with gas-house tar. The world war prevented an immediate capitalization on this important dis-

covery. Since 1918 the number of papers published on experimental tar cancer exceeds one thousand. Many principles have been developed that have practical application in human cancer.

(1) There are marked individual and species variations in susceptibility to the carcinogenic action of tar. The different degrees of susceptibility of individuals of the same species is probably related to heredity. For Lynch found that the incidence of cancer in a strain of mice with a definite cancerous heredity could be increased from 37.04 per cent., which was normal for the strain, to 85 per cent. by painting the skin with tar. But tar will induce cancer in a smaller, but still considerable, percentage of animals without this hereditary tendency. The effect of tar on different species is interesting. Mice are most susceptible to its carcinogenic action, rabbits somewhat less so, while dogs appear to be quite immune. It is almost or quite impossible to produce carcinoma of the skin of a rat with tar, but sarcoma of the subcutaneous tissues can be induced.

(2) For the successful production of tar cancer the degree of stimulation is important. If the irritation of the tar is too severe only simple ulceration usually results; if it is not strong enough, only papillary hyperplasia of the surface epithelium occurs. This necessity for a rather fine adjustment of the degree of irritation is a possible explanation of the failure of many forms of chronic irritation to produce cancer in man.

(3) Cancer rarely develops in mice or rabbits in less than 5 months after the beginning of tar painting, and tar cancer will develop in young animals just as readily as in old ones. These facts have led to a reconsideration of the relation of age to human cancer. Before these facts were known many pages had been written and many theories advanced to account for the more frequent occurrence of carcinoma in persons past forty years of age. The general view was that the passing of the years resulted in disturbances in function or in nutrition of the cells, or in an alteration in the balanced resistance between epithelium and connective tissue which, in some way, prepared the way for carcinoma. Five or more months in the life of a mouse is the equivalent of from 9 to 15 years in the life of a man. Hence a modern explanation of the more frequent occurrence of cancer after the age of 40 is that chronic irritations are not likely to develop before the thirtieth year, and the 9 to 15 years necessary for them to induce cancer would place the onset of the disease in the 5th decade or later.

(4) When a fairly large area of skin is painted with tar, cancer develops in one spot only. If this first cancerous spot is removed another cancer will develop in another part of the painted area. The presence of one cancerous growth in the tarred area exercises a restraining influence on the other epithelial cells which have been equally irritated. This probably is one of the reasons for the fact that spontaneous cancer is unifocal in origin, regardless of the extent of the region irritated. The occurrence of a new but not recurring second cancer in a person who has previously had such a tumor removed is probably an indication that the first tumor was completely eradicated. Carcinoma of the large bowel sometimes develops in the base of one of multiple benign polyps. Only when such a cancer is removed one of the remaining polyps may give rise to a second carcinoma.

(5) Tar cancers metastasize and can be transplanted, if not too badly infected. Hence they behave in all essential respects like spontaneous cancers. For this reason experimental tar

cancer in lower animals has furnished much valuable information applicable to the disease in man.

The second important factor in the causation of cancer is heredity. Dr. Maud Slye in a study of the relation of heredity to cancer in more than 100,000 mice, all of which were descendants of some 7 or 8 original individuals, has concluded that not only a tendency to cancer in general, but also a tendency to organ specificity for cancer are inherited as a Mendelian recessive character. C. C. Little and others have also shown a definite relation between heredity and cancer in mice. These investigators do not agree in the interpretation of their results on the basis of genetics, but they all agree on the observed fact that spontaneous cancer occurs with much greater frequency in mice that have a cancerous heredity.

The fact that these experiments on mice involved a degree of inbreeding never present in human heredity renders it doubtful whether the conclusions derived from them apply with equal cogency to human cancer. Cancer statistics are notoriously unreliable. Careful analysis of as reliable statistics as are available by C. C. Little and others indicate that the incidence of cancer is higher among persons one or both of whose parents died of cancer than among persons without this hereditary background. Cancer of the uterus is rare among Jewish women, and of the breast among the women of Japan. In each instance there is almost complete racial purity due to prejudice against any form of miscegenation. The total death rate from cancer is remarkably alike in all the countries of Europe. But the distribution of cancer among the organs of the body shows a marked variation in different nations. This may be the result of an inherited organ specificity for cancer, kept active by the preponderance of matings between persons of the same nationality. There are, therefore, certain reasonably well-established facts which indicate that heredity is a factor of importance in the occurrence of cancer in man. But an hereditary tendency toward cancer in mice and men behaves as a Mendelian recessive with all the biological implications of that term.

SUMMARY

(1) Cancer is not an infectious disease, is not transmissible and carries no stigma of which the patient need be ashamed.

(2) Cancer cells are derived from the cells of the patient's own body. They undergo some deep-seated change that renders them fundamentally unlike any other cells of the body in any stage of its development. They acquire a new habit of growth, an altered relation to the neighboring cells and to the body as a whole and an abnormal method of respiration.

(3) The most important agencies or influences that induce cancer are heredity and chronic irritation. Heredity furnishes cells some of which are sufficiently unstable that prolonged irritation induces a complete alteration in the nature and habits of one or more especially susceptible cells and they become cancerous. Most cancers appear to be the result of the combined action of heredity and chronic irritation.

ALGAE OF BIZARRE ABODES

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ALGAE grow in many and diverse habitats. They are found in fresh and in salt water, in mountain torrents and quiet pools, on the surface of the soil and at considerable depths, on ice and on snow, from 300 feet below sea level to alpine heights, and from the equator to the poles. Perhaps it should not be surprising that algae live and reproduce in a multiplicity of environments, although the characteristics of protoplasm that permit survival under such extremes are well-nigh inexplicable.

Algae are also more or less intimately associated with numerous other living organisms, both plant and animal. An alga, in addition to the various habitats just enumerated, may live in or on another plant; or it may live in or on an animal. A short list of such animate "hosts" includes bacteria, fungi, liverworts, cycads, magnolias, oaks, tea plants, water fleas, worms, sponges, cockroaches, guinea pigs, ducks and chickens, bears, horses, cattle, sheep, goats, hogs, and even you and me. Truly there are agencies even outside politics that make for "strange bedfellows."

Many species of algae are free-floating and constitute the so-called phytoplankton, or plankton algae. The aquatic forms, exclusive of the plankton, may be roughly termed sedentary or attached. Such plants may grow on almost any conceivable object or substrate: a reed or a rush or some other seed plant, an alga, an animal, a rock or a stone, a dock or a boat or a ship, a shell, the bottom of a lake or the bed of a stream, a log or a stick. The algae may be attached by special hold-fast cells or by stalks and other forms of jelly-like material.

Every one has seen long strands of *Cladophora* in running water; bright green coatings of *Ulothrix* and *Stigeoclonium* on stones of lake margins; slippery accumulations of *Fucus* on rocky seashores; and blue-green blobs of *Rivularia* on sticks and logs in quiet water. Some forms, like *Cladophora* and *Rhizoclonium*, are perennials and may be seen nearly any time of the year. Most of the attached algae, however, are abundant only at certain definite and rather short periods of time: *Ulothrix* in early spring and *Rivularia* in late summer, for examples.

The particular object to which attachment is made appears to bear little or no relation to any specific alga. The greatest factor is undoubtedly proximity to the algae at the time of spore formation. Rough surfaces with small interstices are better sources of lodgment than smooth ones. In fact, the germinating spores of some algae, like *Oedogonium* or *Bulbochaete*, make rather imperfect holdfasts or none at all in smooth glass vessels. Discarded and untenanted snail shells of the rougher sort furnish ideal lodgment for *Cladophora* and *Stigeoclonium* spores which upon germination and growth give the appearance of "life anew" to such gastropodous castaways. Many algae, particularly the larger marine forms, grow on stones and rocks and are called lithophytes.

Partially or nearly submerged stones, sticks and logs may be covered by adhesions of gelatinous material containing in particular blue-greens and diatoms. *Nostoc, Cylindrospermum* and *Oscillatoria* may lie very close to the surface of the substrate; *Gomphonema* and *Navicula* may produce ever-lengthening stalks of mucus that supports the algal cells at some distance from the rock or stone.

Many of the algae discussed above

become planktonic when the warm water dissolves the supporting mucilage. Great quantities of diatoms loosened at one time by a sudden increase in water temperature often form "pulses" in streams. Similar "blooms" develop in lakes and ponds with prodigious rapidity after germination of spores in the bottom mud and rise of the young plants to the surface of the water.

Algae attached to other plants and growing there are referred to as epiphytes. They should not be confused with the colorless parasites which depend upon their hosts for sustenance. Among seed plants we are familiar with epiphytic mistletoe, air plants and tropical orchids. Many kinds of algae, such as *Aphanochaete, Bulbochaete, Stipitococcus* or *Cocconeis,* may grow upon other algae like *Vaucheria, Cladophora* or *Mougeotia.* In aquatic situations the leaf blades, leaf sheaths and stems of practically all macrophytes serve as objects of attachment for algae. Cattails and some smartweeds rarely have abundant algal epiphytes, and it is quite possible that there are degrees of epiphytism among different plants.

It is well known that peripheral parts of most algae are quite gelatinous. The slipperiness and sliminess of filaments of *Spirogyra;* the colonial matrix of *Volvox, Microcystis* and *Tetraspora;* and the enveloping sheaths of *Lyngbya* and *Scytonema* are familiar to all. These mucilaginous coats are excellent habitats for bacteria. In most aquatic forms the association is probably quite accidental, and during vegetative growth the algae and bacteria may bear no relation except as space partners. In soil algae, however, the two members may be mutually helpful in nitrogen fixation. Mass accumulations of algae are doubtless hastened in their decomposition by associated bacteria of decay. Bacteria in the sheaths and coats of many algae are so nearly ever-present that it is practically impossible to grow absolutely pure cultures of some species. Czurda (University of Prague) has been able to get filaments even of such algae as *Spirogyra* free from bacteria by frequent shakings of vigorously growing plants in distilled water.

The non-aquatic epiphyte is perhaps more common to most of us. *Pleurococcus* (*Protococcus*) has been known for years as a name for the greenish incrustation on many tree trunks. It usually occurs on the less lighted or sometimes leeward side of the tree, and rarely grows in latitudes with an annual rainfall of less than twenty inches. It is more common on some trees than others, and this may be due to differences in roughness of bark, humidity of the air or age of the tree. *Trentepohlia* and *Prasiola* are also conspicuous members of what one might call aerial algae: those growing on barks of trees as well as on woodwork, masonry, stones and cliffs not submerged. Aerial algae are thought to require an atmosphere of rather high humidity, even though the area may be extremely localized.

Pleurococcus seems actually to require very little water and so thrives in air of ordinary moisture content. It is characteristic of such algae that they are able to withstand long periods of desiccation without any appreciable injury to the vegetative cells. When moisture becomes available, the plants show rapid increase in greenness and vegetative activity. Apparently the cells are practically impermeable to water during these droughts, and Fritsch suggests that they are then in a state of "paralysis." Their protoplasts contain no large vacuoles, and the protoplasm survives without the customary water supply. Whatever the explanation of such remarkable resistance to arefaction, it is quite evident that something besides visible structural modification is fundamental.

In discussing aerial algae one finds it difficult exactly to delimit and classify. Many observers in tropical regions have been impressed with the prodigious

abundance of aerial and subaerial algae growing on every stone, tree trunk, wall and roof, as well as on the ground. It has even been facetiously remarked that algae are found on some of the more sedentary brethren among the natives, but the writer has not verified such observation. It is true that in regions of excessive rainfall algal mats may be seen growing on almost any conceivable object. The algae are usually dark green rather than light green in color, and the blue-greens loom large in the composition of the flora. Colors vary all the way from bright blue to dark blue-green or nearly black. *Trentepohlia* along with a few other genera of green algae is very abundant, but it is usually some shade of orange-red unless growing in shady places.

Not easily separable from the above are the algae which grow on the leaves of other plants: the so-called epiphyllous algae. They do not differ materially from bark epiphytes and other aerial forms. They apparently suffer little from desiccation because of the high humidity to which they are nearly continuously subjected. Some forms grow in intense light, while others are found in considerable shade. The number of species of epiphyllous algae is probably not large because the same plant may occur on almost innumerable hosts. The number of individuals, however, is doubtless equal or perhaps superior to that of any other group of plants in the tropics, with the exception of the bacteria.

There are various degrees of epiphyllism from the casual epiphyte to the real parasite. Most epiphyllous forms are disk-like, subcuticular or merely place epiphytes. There are, however, a few genera that seem to be restricted to localized leaf areas. One of the most interesting is Palm's *Stomatochroon*[1] which grows in the stomatal cavity of the leaf and is apparently anchored there by a lobed holdfast. The alga consists of a few cells, enters the cavity through the stoma and is found on a wide variety of host plants, both cultivated and wild. It is perhaps the most widely distributed epiphyllous alga of the tropics. Rare in virgin forests of dense shade, it grows on open, sunny weed and bush vegetation of waste and fallow land, on low-growing secondary jungle, on pastures and on garden and orchard plants. The aerial parts of *Stomatochroon* are golden yellow to intense purple or brown, due to a richness of hematochrome in the cells. The basal cell is curiously enough vivid green and devoid of hematochrome.

Passage through the stomata in the case of *Stomatochroon* seems to be merely a matter of growth. It has been reported that amoeboid cells are responsible for the entry into leaves of species of *Chlorochytrium* and *Synchytrium*. *Cephaleuros* gains adit through cuticular and epidermal lesions by zoospores. When the algae are merely surface epiphytes, no apparent injury occurs to the host. Complete covering of areas of the leaf perhaps prevents the penetration of rays of light of certain wave-lengths, but the data are insufficient to draw any inferences. It is when such algae are subcuticular and subepidermal that pathogenicity becomes evident.

Stomatochroon may cause coppery or yellowish-red discolorations of the leaves of the host. True parasitism, or at least pathogenicity, however, is shown by the nearly ubiquitous *Cephaleuros* of tropical and subtropical regions. It grows in Florida, according to Wolf,[2] on grapefruit, sweet lemon, Cuban shaddock, tea, magnolia, loquat, avocado, Spanish jasmine, tangerine, temple orange, cinnamon, fringe tree, shining privet, bay and coral berry. The leaves are usually the parts infected, although the alga may occur on both twigs and fruits. It is sufficiently important in

[1] *Arkiv. f. Bot.*, 25 (A, 16): 1–16, 1934.

[2] *Jour. Elisha Mitchell Sci. Soc.*, 45 (2): 187–205, 1930.

India on tea to be locally known as "red rust."

Cephaleuros normally causes velvety reddish-brown to orange colored cushion-like patches. If the epidermis is smooth, it may be found on both sides of the leaf; if the leaf is hairy on the lower surface, the alga appears on the upper side. It may be purely superficial, it may grow between the cuticle and the epidermis, or it may extend between adjacent epidermal cells into the chlorenchyma. The vegetative portions of the plant then may be strictly endophytic.

On the magnolia such infection is not noticeable till autumn when the leaves are about five months old. The thalli enlarge during the winter, and just prior to the rainy season—eight months after infection—both stalked and sessile sporangia appear. The plant continues to grow, and both sporangia and zoospores are produced throughout the summer, thus spreading the infection. Water and mineral salts are taken from the host by the *Cephaleuros* thalli. Leaf cells adjacent to the alga die without modification in most plants, but in a few, cork formation is initiated. The algal parasite is usually controlled by defoliation, by fungicides and by the cultivation of vigorous plants.

Some groups of algae live almost entirely within other plants and are known as endophytes. Most of them are perhaps merely space-endophytes; that is, occupying the intercellular cavities only. Species of *Entocladia* may grow within the wall layers of other algae, like *Rhizoclonium*. A species of *Chlorochytrium* inhabits duckweeds, hornwort, elodea and some mosses; an *Anabaena* lives in *Azolla;* and a *Nostoc* is found inside the thalli of the liverwort *Anthoceros*. Another species of *Nostoc* grows in the root tubercles of a cycad.

A most interesting group of algae, made up of blue-greens and greens, belongs to the algal constituents of lichens. A lichen is generally considered to be a mutual association of an alga and a fungus, perhaps symbiotic, perhaps not. The fact that one of the associates is holophytic, while the other is not, led to the early conclusion that the two are mutually dependent and beneficial: the alga furnishing carbohydrates through photosynthesis and the fungus offering protection and an added water supply. Perhaps the most remarkable thing about lichens is their ability to withstand extreme desiccation.

Most of the algal constituents of lichens are not aquatic and when free from the fungus grow in moist and shady places as epiphytes or aerial forms on stones and walls and tree trunks. The fungi are largely Ascomycetes.

Algae may also be epizoic. Common examples are *Synedra* on copepods, *Characiopsis* on rotifers and *Characium* on certain crustacea. One species of *Characiopsis*, for example, is often found only on the tail of a small crustacean (*Branchipus*), while another and related epiphyte may be confined to the forward appendages of the same animal. This is certainly a case of ecological definitiveness with a vengeance. Algae are found, in addition, on protozoa, amphipods, water fleas, fishes and turtles.

In summer one can easily get a sizable collection of the attached *Basicladia* (freshwater *Chaetomorpha*) by catching turtles conveniently carrying on their backs firmly anchored tufts of the green filaments. In fact *Basicladia* is one of the few algae that may be identified at a distance, "on the go" and by the "company it keeps." Several species of blue-greens, reds and greens are associated with sponges; in some cases this relationship seems to be symbiotic and will be mentioned later.

Perhaps the strangest algae of all are the endozoic forms. Man has long known that his digestive tract, as well as that of many another animal, contains a regular menagerie of bacteria and protozoa—organisms sometimes annoying and destructive but usually

harmless and perhaps even necessary to comfort and gastronomic happiness. It is only recently, however, that the algae have been found as a part of this strange assembly. Animals aquatic and terrestrial, vertebrate as well as invertebrate, great and small, are now thought to be hosts to certain species of algae, not only in their stomachic and intestinal tracts but even sometimes in the body cavity itself.

The earliest known endozoic algae were probably the "Zoochlorellae" found growing in apparently symbiotic relationship with infusoria (*Paramecium, Stentor*) and especially the green *Hydra*. *Chlorella* occurs in the cells of *Hydra viridis; Carteria* is associated with the worm *Convoluta;* and numerous species belonging to such genera as *Gongrosira, Spongocladia, Struvea, Thamnoclonium, Aphanocapsa, Phormidium* and *Lyngbya* are intimately associated with sponges. A species of *Aphanocapsa* (*A. raspaigellae*) occurs in the cells of sponges growing at depths of from 10 to 25 meters. *Chlorochytrium* is reported to grow in the skin of carp.

It was just about a century ago that Valentin and Farre noted blue-green-like algae from the intestine of the human species. Most of the work on endozoic algae, particularly of vertebrates, has been done, however, during the last two decades.[3] The hosts are numerous. The algae, though apparently strictly parasitic or saprophytic within the animal digestive tract, may become holophytic when removed to a lighted environment. It has been occasionally objected that these internal inhabitants are merely chance visitors from food eaten by the host. The evidence seems clear, however, that actual attachment is made with the intestinal wall and the algae live and grow endozoically for considerable periods of time.

[3] *Annales de parasitologie humaine et comparée (Paris)* 1: 75–89, 113–123, 1923.

A partial listing may suffice to show the ramifications of the ecological propensities of vertebrate-inhabiting algae. *Oscillospira* has been reported from guinea pigs, tadpoles and deer; *Simonsiella* from man, horse, cow, pig, goat, sheep and fowl; *Alysiella* (which by the way looks more like a filamentous diatom than a blue-green) from the pharynx of a hen and from the intestine of horse, pig, sheep and goats; *Anabaeniolum* from guinea pig, man and the rabbit-like rodent, agouti. It should be noted that for the present at least all such endozoic algae are classified with the blue-greens.

The tables may be turned in this queer relationship when the alga becomes host and the animal becomes epiphytic. Vorticellae are very numerous on the blue-green *Anabaena* at certain stages in its life history. Species of rotifers grow within the colonies of *Volvox* and *Coelosphaerium* and inside the cells of *Vaucheria* and *Cladophora*. Many fungal parasites, particularly the Chytrids, infest *Spirogyra, Oedogonium, Mougeotia* and numerous other algae.

When one tries to explain the habits and behavior of one's fellow man, he is often driven to mutter that there is no accounting for tastes. It is equally difficult, on the basis of our present knowledge, to account with any adequacy for the various associations in which algae grow. Some habitats seem natural and call for very little comment; others appear unusually heterodox and bizarre. It is doubtful if any other group of organisms on earth live and grow in more diversified and numerous environments than do the algae.

THE PROPER FUNCTION OF PSYCHO-TECHNOLOGY

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DESPITE the importance of the field and the number of journals and textbooks devoted to the subject, applied psychology—or better psychotechnology—has received so far no very searching analysis of its function. The philosophical and the experimental psychologists have probably, through aversion or envy, ignored the field; the practitioners have been so interested in trying to harvest the fruits of their enterprises that they have, chameleon-like, adopted the approach of hard-headed practical men, and have avoided any close scrutiny of their subject. One guesses they feel they must "play the game." This consists in selling their services to some concern and doing work for that business, or in writing books for public and school consumption that exemplify, in style as well as in content, all the principles and mannerisms of a "selling-yourself" psychology.[1]

The present paper attempts an analysis of psychotechnology and offers a statement of its proper function and problems.

(1) *Science and technology.* What we call the scientific approach to problems arose from its use and extension in the solution of practical problems. Histories of the various sciences show that many advances were made in the course of the solution of daily problems. The scientific approach has spread, due no doubt to the greater success in control its methods attain than do the rival systems of superstition and ritual.

Although many learned men try to slur over the distinctions between science and technology, others have pointed out what seem to be adequate grounds of contrast. While it may be true that the distinctions have been made for the ulterior purpose of defending the scientist's own pet interests as subjects for research against the pressure to get immediate practical results, the distinctions none the less may be quite valid. The fact that men in universities need fortifications about the fields of their research against the inroads of the legislators, administrators and others who would cut off the sources of supplies certainly does not imply that the bulwarks are illusory.

Science and technology, it has been pointed out, are not to be distinguished on the basis of their subject-matter, since the material is common to both; nor in terms of method, since both employ the methods of observation, of experimentation.[2] One might facetiously say that necessity was the mother, and the experimental method the father of the twins.

[1] See, for example, E. T. Webb and J. J. B. Morgan, "Strategy in Handling People," Garden City Publishing Company, Garden City, 1930; G. W. Crane, "Psychology Applied," Northwestern University Press, 1932. Older examples of the content, but without so much stress upon the ingratiating style, may be found in H. D. Kitson, "The Mind of the Buyer," Macmillan, 1921; E. J. Swift, "Business Power through Psychology," Scribner's, 1925; A. J. Snow, "Effective Selling," Shaw, 1929; the style is best exemplified in the many books written by W. B. Pitkin.

[2] A thorough analysis of the distinctions between science and technology, together with comprehensive quotations of the opinions of eminent scientists may be found in E. B. Titchener, "Systematic Psychology: Prolegomena." Macmillan, 1929.

science and technology. The budding occurred, to continue the analogy, when part of the embryonic matrix set out after "knowledge-in-general," while the remainder continued to pursue "knowledge-in-particular" about practical, useful affairs. The distinction is one, then, that has arisen in the modern history of science, and turns out to be nothing more than a difference in the goals, the objectives, the points of view. The scientific man in the university is typically not concerned with particular workaday problems, but with general principles and knowledge. The scientific man in the world of production and distribution of goods must be concerned with the particular problem of how to do something.

Although the difference between a scientist and a technologist may at the origin be so seemingly trivial as an attitude, many striking contrasts develop from this early branching. The man of science is disinterested, impersonal; he is willing to follow the data of his problem no matter where it may lead. He must be willing to forego any interest in the outcome for fear such an interest might bias the results. His aim is to describe and understand nature. As a critical scientist he recognizes that, after all, "explanations" fit only the commonsense approach, and that strictly his laws turn out to be a systematic description of what may be observed under specified circumstances.

In contrast, the technologist has specific interests in the outcome. His problem consists in getting certain results: to build a bridge, to cure a patient. Interesting problems may arise, but can not be followed lest they provide unprofitable distractions. Very often such side projects might even interfere with the success of the project. Psychiatrists often report curing patients the nature of whose malady they did not know, and the reason for the improvement they do not understand; but they must give the patient up for his own good. The technologist's aim is not to describe and to know, but to explain, to predict, to cure. He deals with values, with appreciations, with utility.

Thus the division of science and technology implies even personality differences as well as those of approach, of outcome and of final formulation.

(2) *The function of technology.* Science is a growing body of truth, of descriptions about reality; it is a system of propositions. Technology is a growing body of recipes, of the best ways to do things. It is a system of rules for action.

Any system of action implies normative or ethical judgments. In a certain sense even the scientist must implicitly make some moral judgments. He at least holds that he *ought* to be convinced of the truth of conclusions reached by rigorously following the scientific method. The technologist on the other hand must make, either explicitly or implicitly, types of ethical judgment at every turn. It has been the great weakness of most technologies that this has not been recognized, and their normative fundamentals systematically worked out.

Let us attempt a survey of the implicit foundations of certain representative technologies. The position of the engineer might be paraphrased in this manner: "If you want something (a bridge, a dam, a building), this is the best way to have it done." The engineer does not question very much whether the thing ought to be done. He has not asked himself what is the function of an engineer. This may be due to the historical fact that such technologists have usually had to hire themselves out to some profit-seeking individual or concern in order to practise their chosen field. The business sets the problems. Engineers who have not seen, or have not been able to carry out their functions properly, have been

instrumental in devising, constructing and distributing, say, electric light-bulbs that will burn out in a specified time; safety-razor blades that will last hardly through a shave; liquid fire, poisonous gases for use in war and in industrial disputes; and advertising campaigns that will make people glad to buy shoddy and harmful products.[3] The necessity for managers in a capitalistic system to sabotage in industry was pointed out long ago by Veblen and others.[4] The engineers have failed to see that the function of an industrial system is production and distribution for consumption of goods and not the accumulation of profits. This may be attributed in part to two reasons: the position of the engineer in industry was not such as to envisage the entire organic-like structure of an industrial society, and their training inclined them to consider themselves gentleman members of the same class of society as their employers, to consider they had the same interests and aims, the success of which they were assured could be achieved through the diligent exercise of loyal talent.

Certain consequences of the depression have changed the view of many engineers by clearly demonstrating the basic antagonism in aim and in interest between the technologists trained to serve the needs of mankind and the industrial and financial directors, trained to develop profits on investments even at the expense of the needs of mankind. We may list as illustrations: the exposure of the fairly successful attempt to buy the teaching and writing of "disinterested" professors, especially with regard to the ownership and control of public utilities; the purchase and suppression of economically valuable inventions, and the wide-spread effort to discourage further technological advances and developments; the tendency to discredit the schools and to cut drastically their appropriations, since they not only produce some technological advance but also produce a thin source of enlightened opposition; and finally, of course, the rapid increase of technological unemployment.[5]

The position of the doctor may be paraphrased: "You do want to be healthy and strong, and this is what you need to get and keep well." The physician is more closely connected in his profession with the immediate welfare of mankind than is the engineer, and is rarely in the hire of some corporation that dictates his policies and treatment. The doctor is expected to keep his patients well or to get them well as quickly as can be. While society may look with indifference or even approval upon enterprising business men who urge us to use more of some abrasive tooth paste or who try to frighten us into an addiction for cathartics or smelly mouth washes, society and the Medical Association usually frown with considerable disapproval upon the physician whose enter-

[3] Evidence may be found in the Confidential and Non-Confidential Bulletins of Consumers' Research, Inc., Washington, N. J., and in *e.g.*, S. P. Chase, "The Tragedy of Waste," Macmillan, 1926, "Men and Machines," Macmillan, 1929; S. P. Chase and F. J. Schlink, "Your Money's Worth," Macmillan, 1933; A. Kallet and F. J. Schlink, "100,000,000 Guinea-Pigs," Vanguard, 1933; T. S. Harding, "The Degradation of Science," Farrar and Rinehart, 1931.

[4] T. B. Veblen, "The Theory of the Leisure Class," Macmillan, 1908 (3rd ed., 1919); "The Vested Interests and the State of the Industrial Arts," Huebsch, 1919; "The Engineers and the Price System," Huebsch, 1921; "Absentee Ownership and Business Enterprise in Recent Times," Huebsch, 1923.

[5] The activities of the public utilities have been under scrutiny of the Federal Trade Commission for several years. Popular summaries of the findings have been written by E. H. Gruening, "The Public Pays," Vanguard, 1931; C. D. Thompson, "Confessions of the Power Trust," Dutton, 1932. The plight of the inventor is again indicated by F. J. Fraser, *Common Sense*, 3: 10, 6–9, October, 1934, and 11, 19–22, November, 1934. See also T. B. Veblen, "The Higher Learning in America," Huebsch, 1918.

prise takes the form of recommending costly and unnecessary operations to his patients. Most physicians recognize that the health of their patients is the first consideration, and a high income second.

The lawyer is a professional technician also; and the function of the law is to ease the frictions that arise in society, in a just fashion. But the lawyer even more than the engineer is a hireling representing only the interests of his employer; a mercenary who fights with equal skill and vigor on either side.

Applied psychologists, like lawyers and doctors, deal with human beings; and psychotechnologists have, like the lawyers, made their scanty living by selling their talents to business men. They hire out as super-salesmen, vocational selectors, scientific managers, as experts in soothing, mollifying and motivating the workers for the enrichment of their employers.[6] But this is hardly the proper function of psychotechnology.

(3) *The functions of psychotechnology.* The science of psychology has an advantage with regard to its subject-matter over the other sciences in that it not only may make objective determinations and measure of the behavior of its subject-matter, but can also obtain reports of the actual quality and experience of this subject-matter. Where an engineer can say how to get electric power some place (if you want it), where a doctor can say how to get out your tonsils (if you don't want them), the psychologist can say how man can get satisfaction in life. The psychologist is in a position to determine the fundamental needs and requirements of mankind, the satisfaction of which should constitute an approach to the best life. The function of psychotechnology is to determine the conditions of living necessary for a complete and satisfactory life, and to elaborate the methods for such attainment.

The elaboration of this notion of psychotechnology requires an essay possessing the magnitude of a book. The main lines of its development may briefly be indicated.

What are man's fundamental drives and motives? It appears obvious that the conditions of a complete and satisfactory life are functions of the biological and psychological characteristics of the creature doing the living. The good life for the crayfish certainly should differ in essential respects from the good life for a kangaroo; but there will be certain general conditions common to them, since they are both living creatures. The differences in detail as to the good life for various classes of animals will hence depend upon the elaboration of requirements for the expression of their special biological talents, and the satisfaction of their special cravings. From a biological standpoint a good life involves satisfactions from the fulfilment of the socially adjustive, adaptive behavior patterns. Can we agree that every animal has its characteristic genus nature; that it is satisfying for the creature to develop and express this nature; that it is unsatisfying to thwart, pervert or distort this nature?

Psychologists currently list as drives or appetites such things as thirst, hunger, nausea, lust, fatigue and the need for activity, proper temperature conditions, air, elimination, the avoidance of painful objects and the continuation of

[6] There are about 40 members and associates of the American Psychological Association now or recently in the employment of some concern, such as the J. Walter Thompson Company, Procter and Gamble, Sears and Roebuck, R. H. Macy and Company and Western Electric Company. For the type of work that has been done by psychologists see M. S. Viteles, "Industrial Psychology," Norton, 1932; A. J. Snow, "Psychology in Business Relations," McGraw-Hill, 1930; H. C. Link, "The New Psychology of Selling and Advertising," Macmillan, 1932; H. W. Hepner, "Human Relations in Changing Industry," Prentice-Hall, 1934.

pleasant and soothing objects. This list must be incomplete, for these drives are essentially visceral and automatic. These drives are common to most mammals. The list looks as though it were designed for contented cows, rather than humans. Satisfaction of these appetites is necessary, of course, to a good life for man; but they are not alone sufficient. In children and adults we can find almost universal evidence of curiosity, exhibitionism, interest in friends and in their esteem, self-esteem, self-expression and similar interests. Where do these potential satisfactions arise? Are they simply conditioned upon the satisfactions we get as infants when fed and petted by our mothers, or do they have some more fundamental biological (and hence racially permanent) basis? Biologists point out that the chief and distinguishing feature of mankind is individual variability, the capacity to learn. Our social culture is a matter of training. Psychiatrists point out that where society persistently denies to some of its members the satisfaction of basic cravings, these individuals develop psychopathic behavior. By a survey of such psychopathic behavior one can determine in part at least man's fundamental drives and cravings. G. V. Hamilton points to five major needs: a productive occupation; access to familiar sources of gregarious satisfaction; freedom to pursue and opportunities for pursuing various sexual-romantic values; harmonious domestic conditions; and conditions that make for the incidence of considerable variety of stimulation.[7] The last item is broad enough to include creative activities on the part of the more highly endowed. Although our present society fails to provide any large proportion of its members with all these types of satisfactions, no one can justly deny that society now has the technical training and equipment to provide practically every one with the first, second and last of these five classes of satisfactions. The items with regard to sexual-romantic and domestic conditions are, certainly, matters more of individual personality and taste rather than matters of engineering. Present society fails here through the improper training of the personality of its members.

What criteria and standards should be followed in developing the personalities of adults? The adult is not simply the child grown large. The variety of human cultures, primitive and civilized, attests to the plasticity of human nature within the wide boundaries set by our biological heritage. We must trace the development of the personality from egocentric childhood to socialized maturity. What are the conditions requisite for the establishment of those adult motives best suited for the good life?

Perhaps we should start in a negative way, by trying to eliminate the development of criminals, prostitutes, deceivers, scolds. But it soon appears that to stop the increase of such characters will actually involve the reconstitution of society. There must be a revolution in our attitudes and values. For it appears that the attitude of the burglar or gangster with regard to society is essentially the same as that of the munitions manufacturer, the mortgagor, the capitalist. They seek their own benefit at the expense of some one else. The robber, of course, does his business only in retail rather than in wholesale fashion and he lacks the tactical advantage of the support of the government. The proper attitude for us to have with regard to things is one of mastery and control; with regard to people, one of kindly sympathy, of allied following or leading. Most of the evils of the world come when we try to dominate other people by force for our own benefit.

[7] G. V. Hamilton, "An Introduction to Objective Psychopathology," Mosby, St. Louis, 1925.

Perhaps the most fundamental thing for us to learn is that humans are social creatures; and that it is far better to cooperate than to compete. A human being who wants to play the lone wolf is not a social creature, and the protection of society requires that he be removed from circulation. He is trying to live at the expense of his brothers: by the exploitation of people with whom he should be on friendly terms. We need to emulate the ants. Each colony of ants is one big family, the members of which cooperate to do their share of the work of the community. There is no place even for rugged wolves in a social system.

The final problem has to do with human efficiency and the economy of human energy. This is the field of applied psychology that has been widely developed, not in the interests of society at large but of those predatory interests that our haphazard civilization has permitted and even encouraged to develop. The same techniques are applicable on a wider scale. The rôle of the psychotechnologist concerns (a) the measurement of individual differences in aptitudes, abilities and interests and their proper and satisfactory utilization. With 12 to 15 million unemployed in our present unsocial society, to talk and to teach vocational guidance is viciously to jest. Yet there is elaborate equipment ready and waiting for practical use, once the mass of the members of society decide to follow the ants rather than the wolves.

Within industry the psychotechnologist (b) can aim at the elimination of fatigue and monotony. This can be accomplished in part by the introduction of proper rest and recreation periods, by the determination of the best methods of work, by fitting the machine to the worker and by determining and maintaining the optimal conditions of ventilation, illumination and the like. The analysis of the conditions and methods best suited to particular tasks that must be done will aim to achieve the maximal ease, comfort and efficiency of output. Another significant problem (c) involves the personnel relations within the industrial concern.

We are aware of our technological power to utilize nature; but we try to exercise such power over other humans. When will we recognize that we are all members of a society? The field for exploitation is the resources of nature. Let us use the methods of science for proper exploitation and for the mutual, social good.

WHAT IS A SYLLABLE?

By W. L. SCHRAMM
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THERE exist two radically different ideas of the syllable. With one the literate world has long been familiar; the other has become popular only in the last thirty years. According to one conception, the syllable is a "sound uttered with a single impulse or effort of the voice, and constituting a word or a part of a word"; in printing and spelling it is a group of letters separated, as at the end of a line, from the rest of a word or the rest of a sentence, and "capable of being uttered with a single impulse of the voice."[1] According to the other conception, there is no such thing as a syllable.

The former of these has a long tradition behind it. The earliest Greek rhetoricians spoke of the syllable. Classical verse was explained in terms of long and short syllables. In the Elizabethan age of England the Areopagitica came into existence because poets were not sure whether to form their meters with long and short syllables or loud and soft ones. At the present time, a great body of European verse is supposed to be written according to the principle of "syllable counting," whereas English and other Germanic languages base their meters on "stressed and unstressed syllables." For centuries, schoolboys have learned to spell out their words by syllables; and the ancient scribe was taught, as is the modern stenographer, to divide his words according to an established system of syllabication. This tradition has never doubted the existence of a syllable, and such a tradition is too firmly rooted to be dislodged easily.

The other conception has behind it the weight of scientific measurement. Since the late nineteenth century when the Abbé Rousselot and others first applied the photography of sound to the study of speech, psychologists and phoneticians have become increasingly impatient with the use of the word "syllable" to denote a unit of speech. They have found that connected speech is a flowing current of vocal melody, broken only by such things as stopped consonants and phrasal pauses. In most cases, they are quite unable to find within a word or a phrase definite points at which the sound might be divided into units called syllables.[2] They feel, therefore, that the syllable is a visual, rather than an oral and auditory unit. They ask, in all justice, that a language should be analyzed according to the way it sounds, not how it looks; and in opposition to the syllabic tradition they offer their photographs and their charts, and challenge the doubters to inspect the evidence, and find syllables if they can!

In the first place, connected speech is a continuous flow. The old tradition visualizes connected speech as a chain made up of links, each link a syllable. Supposedly, one could remove a link from any point in the chain and study it. But the phonophotographs have re-

[1] These statements are based on text-book and dictionary definitions of the syllable. The quotations are from Webster's New International.

[2] It has become the fashion to speak of "speech atoms"—small portions of the speech inscription "during which the character of the movement remains practically unchanged"—and of "speech molecules"—portions of speech set off by breaks in the sound. See F. Janvrin, "The Atomic Structure of Speech," in *Archives Néerlandaises de Phonétique Expérimentale*, Tome VI (1931), 101–04.

vealed no such structure. The only breaks within the speech current are those created by the ending of a phrase, by an interphrasal pause for the sake of elocutionary emphasis or by stopped consonants. The scientist conceives the speech current, therefore, not as a chain made up of detachable links, but rather as a metallic bar, which may vary in size and composition along its length, but which is still a unit.

In the second place, there is no definite point, except those mentioned above, where one kind of sound may be said to replace another. The syllabic tradition has conceived of speech as something like the shifting of gears in an automobile. The driver pulls the lever into the left rear position and the car moves in low gear; he shifts the lever to right front, and the car is in second gear. And so a speaker sets his vocal organs in one position, and says a certain vowel; he shifts the position and says another; and thus throughout his sentence. This belief is an outgrowth of the theory that vowels and other speech sounds are the products of *positions* of the vocal organs. It has now been shown by means of x-ray photographs and the registry of sound that speech sounds are the results of *movements*, rather than positions.[3] The vocal organs glide smoothly through a phrase, and there is no sharp and definite point of delimitation between one vowel and another, because the quality of the sound changes gradually with the gradual movements of the tongue, the pharynx, etc. Let us take an example. A speaker is pronouncing the word "alone." There will be observable on the phonophotographic film a period when he is known to be pronouncing the first vowel. There will be a following period when the "l" sound is beginning to creep into the vowel. Then there will be an almost pure "l" sound, then a combination into which the second vowel is entering, the second vowel, nasal elements in the registration which indicate that the "n" has appeared, and finally a slight explosion to indicate the release of the nasal. No observer can select the point where the "a" ends and the "l" begins. Phonologically the word is indivisible into syllables. To return to our former illustration, we may say that the human voice has been shown to be a very flexible instrument which does not need to change gears to change sounds. In the Germanic languages, at least, the glides between sounds are so gradual that it is usually impossible to distinguish a point of demarcation.

Although the measurement of sound has been developed to a point of great accuracy—pitch can be measured to 1/1000 of a tone, intensity to 1/10 decibel, time to 1/1000 second, timbre to one per cent. of change in harmonic composition—there is no system of measurement in existence which can delineate either boundary of a syllable unless that syllable is initial or final in a phrase or is bordered by a voiceless consonant. Even in the latter case there is grave doubt as to where the consonant belongs. For example, the first syllable of the word "opera" is, by tradition, "op." The photographic measurement of this word shows a certain amount of time expended in pronouncing the vowel "o"; then a pause, while the lips are closed preparing the "p"; and finally the explosion of the "p" and the next vowel. The problem is, where does the

[3] See E. W. Scripture, "Zur Psychophysik und Physiologie der Vokale," *Zeitschrift für Sinnesphysiologie*, 58: 195–208, 1927; "The Nature of the Vowels," 1931; and articles in *Zeitschrift für Experimentalphonetik*—especially "Die Natur der Vokale" (1928). Professor Scripture has expressed an opinion almost at the opposite extreme from the traditional idea of the production of vowels. "Exactly the same vowel can be produced by very different movements," he wrote in 1931. "There are no 'cardinal vowels' with typical tongue positions; different persons make the same vowel with utterly different movements" —"What is Experimental Phonetics?" *Modern Languages*, February, 1931.

second syllable begin? Phonologically, there is no more reason to count the pause with the first vowel than with the second. Even if it is given to the first vowel, does the second syllable begin exactly at the end of the pause, or must some of the duration of the sound after the pause be accredited to the "p"? Such cases as this cause a scientist to lose patience with the syllable. And it is true that from the standpoint of one who considers a unit of speech to be a definitely delineated part of speech, the syllable simply does not exist. More nearly exact units are the speech atom and the speech molecule.

In the third place, there is grave doubt concerning the traditional theory of the production of a syllable. "A syllable is a sound capable of being uttered with a single effort or impulse of the voice"—that is a part of nearly every definition. Yet the simplest phonophotograph will show that a great many of the units commonly called syllables are *not* capable of being uttered with a single effort or impulse of the voice. This is especially true of monosyllables. Any monosyllabic word which ends in a plosive or in a plosive followed by a spirant requires more than one impulse of the voice. Such words as *plot, take, bad, bog,* require two definite sounds. The lips close before the plosive, there is an interval of silence, and then the lips open and the explosion takes place. Are these to be considered disyllabic? And are such words as *whisks, mosques, asks,* to be considered trisyllables? This is surely a serious objection to our traditional conception of the syllable.

But we can not argue the syllable out of existence quite so easily. For thousands of years we have been hearing elements of speech which we have called syllables, and when we have written we have not hesitated to indicate those syllables by means of letters. It may be well to inquire what we have been hearing. When we hear a line of verse we can usually tell how many syllables it contains. What do we mean by this? We mean, usually, that the line contains a certain number of stresses. The syllable usually has a definite stress of its own, and at the high point of that stress it has a tone quality different from those of the stresses around it.

A line of verse or a phrase of connected prose may be thought of as a mountain chain. The peaks are of different heights; they are of different shapes and colors; and, although they are strung together like bumps on a central ridge so that one is never sure where in the intermediate valley one ends and the other begins, still one never doubts their identity. If he climbs one peak he knows he is not on the mountain to the east, although he might not know exactly how far eastward he would have to walk before his mountain ended and the next one began. When he stands in the distance he can see that there are a certain number of peaks. So it is when one hears a line of verse or a phrase of connected prose. He is conscious of peaks which are of different heights, shapes and colors, although he is unable to tell precisely where each begins and ends. Fig. A shows the mountain chain of speech. Here we have an intensity curve of a line from Antony's speech in "Julius Caesar" (III, ii). It has been traced from a phonophotograph in such

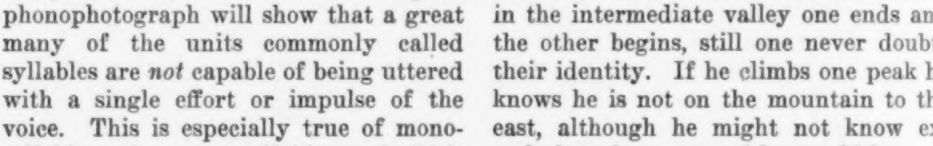

FIG. A

a way that the height of the peak is proportional to the loudness of the sound. You will observe that there are as many peaks as there are syllables. Because a definite delineation is not always possible is no reason that these syllables do not exist, any more than mountain peaks do not exist. We may admit that a syllable is not a quantitative unit, without admitting that it is not a qualitative one. It may not be a useful unit of duration, but it may still be a useful unit of quality and intensity.

It does not seem necessary, therefore, to abolish entirely a term which has been useful for thousands of years, but if we are going to continue to use that term it is only reasonable to reappraise it, to define it clearly in the light of our new knowledge, and to use it more carefully. Our new knowledge of the syllable may be summarized under three heads:

(a) We may as well admit that our visual conception of the syllable, our dictionary and spelling-book division of a word has no justification other than custom in use, convenience in teaching, and descent from languages which added many endings to indicate case, tense, number and gender. We may as well admit that our stenographers are forced to learn a purely arbitrary system of division which is neither more handsome nor more correct than several other systems; that our school children are taught to syllabicate by a system which, if carried into vocal practise, would result in an unnatural pronunciation; and that when we divide a line of verse into syllables we are treating an auditory matter by a visual rule, and moving farther and farther from the intent of the poet and the beauty of the verse. A syllable is not a group of letters.

(b) We may as well admit also that, except in certain special cases, the syllable is of no use as a unit of duration. That is not to say that a syllable does not give the *impression* of duration. It does; but what we have measured as the duration of syllables has been the duration of certain units of sound plucked out of connected speech by an arbitrary rule. It has been the custom, for example, to determine the length of a syllable by measuring the time between the points of lowest intensity on either side of its peak.[4] This method is of some use in studying rhythm, but it is not a measurement of *syllable* length. It is a measure of a purely arbitrary unit of speech.

(c) Until more delicate investigation proves otherwise, we may consider the syllable to be the seat of a stress, differing from its neighboring stresses either by intermediate silences, by different tone color or by an intermediate diminution in stress; and if we must place the syllable definitely in time we may locate its center as the highest point of the energy applied to it—the top of the peak which its intensity builds up and upon which its tone color is distributed.

A syllable, then, is not a definite part of a word; it is, rather, a dynamic phase of a word, and "syllability" (*Silbigkeit*) has been suggested as a more accurate explanation of that character. "Es gibt Silbigkeit aber keine Silben," declares Professor Scripture.[5] But it seems hardly necessary to change the word, as long as we recognize clearly that our visual system of division into syllables is mostly a pleasant fiction, that the syllable is of no practical use as a unit of length, and that when we say a word has a certain number of syllables we mean merely that it has a certain number of important stresses and a certain number of distinctive tone qualities coincidental with those stresses.

[From the Psychological and Phonetic Laboratories of the University of Iowa.]

[4] This method was used in my article, "Time and Intensity in English Tetrameter Verse" (*Philological Quarterly*, XIII: 1, 65–71, 1934). Since then I have come to think that a more accurate study of rhythm may be made by measuring from peak to peak.

[5] E. W. Scripture, *Grundzüge der Englischen Verswissenschaft*, 27. See also his article, "Die Silbigkeit und die Silbe," *Arch. f. d. Stud. d. Sprachen*, CLII: 74, 1927.

SCIENCE SERVICE RADIO TALKS

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WHAT COSMIC RAYS TELL US

By Dr. H. VICTOR NEHER

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"COSMIC" comes from the Greek word "cosmos" and means an orderly and harmonious universe. "Cosmic ray" then refers to a ray coming, not from a chaotic, but from an orderly universe. It is a name applied first by Dr. Robert A. Millikan, of the California Institute of Technology, when he showed beyond all reasonable doubt that there was a very penetrating ray, or radiation, coming in from the space around us. Such a name is exceedingly fitting, for with all our modern methods of prying secrets out of nature we have come back more and more to the old Greek idea of essential order and harmony, of a purposeful universe, each part of which plays an essential rôle in the scheme of the whole.

That man was so long in ignorance of this radiation is not surprising, for it is only in very recent years that he has developed means of detecting its feeble influence. But so keen has been the interest and so rapid have been the developments that to-day we have three separate and distinct means of detecting and measuring cosmic rays. Nor has this interest been limited to men of science. The layman has shown an eagerness for knowledge and a desire to cooperate which has greatly aided the acquisition of new facts so that all might know more of what cosmic rays have to tell.

The search for new knowledge has caused men to risk their lives on ventures to the far-flung reaches of the world. This has always been so and will always be so. It provides the romance of adventure and the means of satisfying man's innate curiosity to know more of the world in which he lives. It has been the means of freeing him from the bonds of ignorance and superstition; it has given him confidence in himself where now he is ruler of the world around him instead of being ruled by that world.

In the truest sense of the word man's quest to know more of what cosmic rays have to tell is a romantic story. The earth is his laboratory, and all that there is in it he uses to further this end. His quest has led him into the northern and southern arctic zones and to equatorial regions. It has caused him to climb the highest accessible mountain tops and to sink instruments into deep lakes. He has flown in huge airplanes to great heights carrying shields of lead weighing half a ton to make soundings higher than could be reached on mountain peaks. The same quest has been the chief scientific object of all flights into the stratosphere, and without doubt many another trip into the high reaches of our atmosphere will be made for the same reason.

The search goes on, but let us pause to take an inventory of some of the major things that cosmic rays have to tell us. Our procedure will be, first to ascertain the facts and second to formulate a theory which will be self-consistent and which will point the way to new experiments and eventually to new facts.

One of the very first and one of the most important discoveries made was that this radiation is the same day or night. This at once tells us that it can not come from the sun. We would next suspect the stars, but here also when the greatest number of stars is in view, namely, when the Milky Way is overhead, we find no change whatever. These facts alone seem to point to an origin in space itself. Of this we are still in doubt, but let us consider some further facts.

Comparison between northern or southern latitudes and equatorial zones reveals a distinctly less amount of cosmic radiation in the equatorial region. Many theories have been advanced to account for this, but the most likely is the influence of the earth's magnetic field. To understand how this might be possible, let us recall that the earth is an enormous magnet with a north and south pole and that electric charges moving in a magnetic field are deflected to one side. At least part of what we call cosmic rays, then, enter our atmosphere as electrically charged particles. Those arriving at or near the equator are more strongly influenced by this huge magnet than those coming in near its poles. Some, or perhaps most, of them are thus eliminated near the equator before they reach the earth. We may call this decrease as the equator is approached the "latitude effect."

Now, surveys of the past have disclosed a marked difference in the magnetism of the earth between the eastern and western hemispheres, it being much weaker in the western. Cosmic rays tell us much the same story, but they tell us more, for their story is their history after having been under the influence of the earth during the last ten to twenty thousand miles of their journey through space. They thus furnish a means for the first time of studying the properties of the earth's magnetism at great distances. This difference in cosmic radiation on the two sides of the earth is called the "longitude effect."

It appears, however, that these particles which cause the latitude and longitude effects do not tell the whole story, for it seems impossible at the present time to explain all the facts on this basis. That there are some charged particles coming into the top of our atmosphere we feel certain, but there must also be a radiation of a different sort which forms other charged particles in our atmosphere and accounts for the major part of the radiation. This second kind of ray appears to be light-like in nature and to have the ability to penetrate several hundred feet into the earth. It is near the equator that we can best study this latter type of radiation, for there the number of external particles mixed in appears to be comparatively small. Much of the work in the future will undoubtedly be done in the equatorial regions, for it has become increasingly evident that here the properties which will tell us most of the nature of cosmic rays are best defined.

These charged particles we have been speaking of are called electrons—the smallest bits of electricity and mass known. The energy of some of them is enormous. There is a hundred times as much energy in some as they would receive from the longest lightning flash, and because of this energy can penetrate several feet of lead with ease.

At sea level the number of particles striking every one of us and going completely through our bodies is from ten to fifteen every second. That we are unaware of them is not strange, for in the first place they are exceedingly small and in the second place they are few in number. Although each and every particle affects us to some extent, the result of even the hundreds of thousands of these particles penetrating our bodies every day is too small to be no-

ticed. What may have been the accumulative effect on the biology of life on the earth throughout all time one can not even guess.

If we were to go to the top of Pike's Peak or fly in an airplane at 14,000 feet we would be exposed to four times as much radiation as we get at sea level. Going to great altitudes the cosmic rays increase very rapidly until at the height reached by stratosphere balloons the occupants of the gondola are struck by several hundred times as many particles as at sea level.

Although the facts are not all in it is nevertheless possible to make intelligent guesses as to the origin of these rays. Dr. Millikan made the stimulating suggestion a number of years ago that they resulted from the act of building the heavier elements, such as helium, oxygen and iron from the lightest of the elements, hydrogen. This process was assumed to be going on in the intense coldness of space. Sir James Jeans has championed the idea that they result from the destruction of matter altogether. A third possibility, suggested by Dr. Fritz Zwicky and Dr. W. Baade, is that stellar catastrophies known to astronomers as super novae may be the origin of these rays. At times an inconspicuous star will suddenly increase in brilliance many thousand fold, reaching temperatures reckoned in millions of degrees. Its maximum brilliance lasts for a few days and then it gradually subsides, usually diminishing to such an extent that after a few months it can no longer be seen. The nova which appeared in the constellation Hercules in December of last year, even though it became one of the brightest stars in the heavens, owed its brilliance to its nearness and was not of the super-nova class. So far there is no conclusive evidence that this nova is giving off cosmic rays. Still a fourth possibility is one suggested by Professor Le Maitre. He wishes to view the present existence of cosmic rays as evidence of bygone days when the universe was young and unstable, and now that it has reached a more mature age, has stopped its frivolous ways, but the remnants of its past are still traveling through space, striking whatever might cross their paths.

Whatever may be the ultimate story cosmic rays have to tell, certain it is that it will be of interest to all. It may be a story of the formation of new matter or the death cry of old. Time only will bring an answer. In the meantime the search for new facts goes incessantly on, but still more incessantly come the cosmic rays themselves, undiminished and undisturbed, fulfilling some as yet unknown purpose in the general scheme of the universe.

ENDOCRINE FACTORS IN PERSONALITY

By Dr. R. G. HOSKINS

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Every one knows in general what personality is, but no one has satisfactorily defined it. It includes everything that gives individuality to the individual. The problem then is, what do the glands contribute to the make-up of the particular self of each of us?

Every one has many glands. These are actually living chemical laboratories. Well-known examples are the salivary glands that keep the mouth moist, the tear glands which upon occasion cause salt water to trickle down our cheeks or the glands in the skin that help keep us

cool in summer. These all take from the blood that courses through them different substances which are combined to form secretions. These secretions then pour through ducts to their various spheres of action. The glands which we are to consider, however, are different from those mentioned. Their secretions instead of being discharged through ducts are returned directly to the blood stream. Thus they are distributed throughout the body to produce a large number of important effects. These regulatory substances are known as the internal secretions or the hormones.

The hormones are among the most powerful of all known drug substances. For example, each of us has in circulation in his body at any one time about one fifth of a grain of a necessary hormone from the thyroid gland. In the course of a year we use about three and one half grains of this substance all told. This is a little more than the equivalent of half an aspirin tablet. Yet we are all dependent upon this small pinch of material substance, thyroxin, to keep us from becoming complete imbeciles—the statement is literally true. Without thyroid secretion the human being becomes merely a sort of walking vegetable. There are several other hormones equally potent, or even more potent, upon which we are fatally dependent either for existence itself or for the ability to make existence worthwhile. All these affect personality.

From certain writings of recent years one might get the impression that personality depends upon little else than hormones. Such is emphatically not the case. Many factors go into the determination of individuality. In the make-up of the personality the two most important features are the mentality and the emotions. The quality of the mind determines whether the individual is intelligent or stupid. Intelligence depends primarily upon the kind of brains one gets from his ancestors, but development of the brain as well as the way it works is to a considerable degree determined by the hormones. Even more important than the intelligence, however, are the emotions. We like one person because he has a jolly, sunny disposition and dislike another because he is glum or conceited. The emotions are closely related to the instincts. Indeed the emotions might be said actually to represent the way the instincts feel to the person who has them. The instincts are substantially determined by hormones both in their quality and in their intensity.

We may now consider some of the glands individually. Suspended from the brain in the center of the head is the pituitary gland. When this gland fails to develop properly the individual remains of small stature throughout life. His littleness sets him apart from others of his age and this very fact of being different reacts upon his personality every day. He is always under an inner necessity to try to compensate for his appearance of physical insignificance.

Should the pituitary become overactive during childhood the result is over-growth. There is now living in a Middle Western state a boy of 17 who, because of the possession of an over-ambitious pituitary, is over 8 feet tall. He can readily tuck his full-sized father under one arm and carry him about the house. Should over-activity of the pituitary begin after the child has grown up a different state of affairs arises. No longer is symmetrical development possible, but the excessive growth takes place only in selected parts of the body. He becomes a gorilla-like monstrosity, a so-called "acromegalic." His deformities have of course a constant tendency to warp his personality. But he has more to contend with. During the early stages of the over-growth he is vigorous and virile. If the distortion is not too great he may even turn it to advantage

as once did a celebrated baseball player who had this disorder.

With his enormous hand and powerful muscles he was able to pitch a remarkably deceptive curved ball. He was alert and resourceful. But after awhile the large pituitary gland began to fail, as it commonly does both in giants and in acromegalics. The case of the baseball player is rather typical of what occurs in such cases. After a few years he began to slip. He lost his muscular control, became timid and hesitating and after a very few seasons in second or third rate teams he left baseball and spent the rest of his futile life as a pool-hall loafer. He was first a brilliant success by virtue of his pituitary secretion and ultimately a pitiful wreck when he was deprived of this stimulating hormone.

Another hormone from the pituitary determines sexual development. Should this hormone not be secreted in proper amount the individual remains throughout life sexually and emotionally a child. The fanatical reformer is likely to be a person of this type. Having no possibilities in himself of satisfying self-development, he attempts to compensate by making over the world, and thus gaining a sense of power.

From the pituitary another secretion that regulates milk formation has recently been discovered. During the later stages of pregnancy and after the birth of the infant this hormone aids in keeping up the maternal food supply for the child. It is definitely true in experimental animals and probably will prove to be true in human beings that this latter hormone—prolactin it has been called—is an important factor in setting up and maintaining not only milk secretion but the maternal instincts as well. Under its influence unmated female rats have been made to adopt and mother large families of babies and roosters have been made to cluck. I would not care to say that human mother love is merely a matter of hormone chemistry, but I suspect that the future will show prolactin to have a significant part in this emotion.

In the lower part of the neck lies the thyroid gland. When its secretion is completely lacking the individual lives at only about half the normal vital speed. He is listless, mentally stupid and sluggish of memory. Aside from a tendency to subdued truculence his emotional life is almost colorless. Fortunately, thyroid deficiency of this marked grade is rare. Unfortunately, however, lesser degrees of thyroid deficiency are quite common and are frequently overlooked even by excellent physicians.

The victims are likely to be overweight, though this is by no means always the case. They fatigue easily and on slight provocation become cross and irritable. They are able to pull themselves together for brief periods but soon relapse again into their feeling of inadequacy. Statistics on this subject are not available, but it is altogether probable that a considerable proportion of the unfortunates who go through life labelled "neurasthenic" or "psychoneurotic" are victims of this mishap.

Let me emphasize that there are many other causes than thyroid deficiency for this state of affairs, but in those cases in which it is the cause the condition is readily corrected. Sometimes even as little as one tenth of a grain of thyroid substance a day is sufficient to add materially to individual comfort. Commonly less than one grain a day is needed.

Unfortunate as are the results of thyroid deficiency even worse is the opposite condition. Over-activity of this gland gives rise to a condition of alert tenseness by which the person may be driven to death. He may live at twice the normal speed. Even with a voracious appetite he is unable to keep the vital furnace adequately stoked and often literally burns himself out.

The thymus gland in the upper part

of the chest has long been under study, but until recently little convincing evidence of its importance had become available. It was believed to have something to do with development and that when it was defective the individual remained weak and futile in his personality. Within the year, however, it has been reported that thymus extract can produce in the offspring of treated animals a remarkable precocity of development. When only a few days of age the baby rats were as advanced as they should have been in a month. It is as though human children were ready for high school at the age of three years. The extract has not yet been tried in any extensive way on human beings, but the experimental evidence suggests that it may some day prove to be an important resource in the treatment of retarded children.

The adrenal glands which lie just above the kidneys also contribute to personality. From these glands is derived the well-known hormone "adrenalin." It is probable that this secretion plays no significant part during times of ordinary quiet existence, but that under emotional stress it is discharged from the gland and has important stimulating effects, that permit us better to muster our bodily resources to meet emergencies. Without the aid of adrenalin we should no doubt be less competent in emergencies and our personalities so much the less effective. In the primitive scheme of existence emergencies called for activity—and adrenalin secretion was probably always helpful. Nowadays, however, emergencies often call, not for immediate activity, but for self-control and calm thinking. Nevertheless, in such conditions the adrenal glands still pour out their stimulating secretions and thus add to the difficulty of remaining calm and collected. It is this behavior of the adrenals which probably gives much of its point to the old saying that "worry is worse than work."

From the adrenal gland is obtained also the hormone "cortin." This substance has only recently become available and its properties are not well known. It seems to influence all the living cells of the body. When cortin secretion fails the individual develops Addison's disease, a condition in which the personality suffers. The patient becomes physically weak, restless, irritable and uncooperative. When cortin is supplied artificially there results a restored sense of well-being, of energy and of enthusiasm. So much for extreme conditions. What part cortin may play in ordinary everyday life, and especially its influence upon the personality, have not yet been adequately studied. There are on record a few cases in which the adrenal glands have become enlarged and in which the individual, whether male or female, acquired a marked accentuation of masculine attributes. These cases suggest that the adrenals may contribute a quality of virility to the personality, but the quality has not yet been obtained in adrenal extracts.

Finally a few observations may be made about the sex glands. From time immemorial these organs have been removed from farm animals to bring about docility of temperament and to facilitate fattening for market. When the glands are removed before maturity either in animals or in human beings the result is essentially the same in all cases. The individuals fail in sexual development. They are more or less lacking in vigor and initiative, though the operation is not actually the ruinous calamity that it is popularly supposed to be. In the experimental animal the mating instincts fail to develop and in the human subject normal romantic interest in the opposite sex is not acquired as the individual reaches adulthood. When the operation is performed later in life the

effects are somewhat variable. A certain degree of instability of temperament is likely to develop and, in women especially, unusual irritability may be apparent. Individuals of both sexes tend to become over-weight.

The foregoing constitute but a few of the outstanding facts which bear on the subject. The relation of the hormones to personality is one of the most interesting and perhaps is the most important topic in the whole field of the internal secretions. Unfortunately, however, the psychological has been the most neglected aspect of the subject. The result is that this important chapter remains yet largely to be written.

Nevertheless, we can safely say that the personality is importantly determined by the influence of hormone factors. There are several hormones, the complete lack of any one of which would essentially ruin the personality. Without his hormones no individual can be normal either physically, mentally or psychologically. Recognition of this fact, however, should not blind us to the further fact that personality is a very complex matter and is dependent upon many other than glandular factors.

PREVENTION OF FOOD POISONING

By Dr. K. F. MEYER

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This program is addressed to all people who believe they have experienced a touch of so-called "ptomaine poisoning." Theoretically, therefore, I should be speaking to practically every one in the United States, for in spite of the fact that there is no such thing as ptomaine poisoning it is one of the most popular of indispositions. It is a blanket term applied to any ailment that appears to have its origin in the stomach and to have been caused by the ingestion of some questionable food substance. As a matter of fact, there are a dozen different causes which may underlie those excruciating symptoms which lead us to sigh, "It must have been something I ate." Some of them are not due to the nature or condition of the food at all but to misuse of the food or to our own peculiarities, temporary or permanent. Others are due to different kinds of food poisoning.

Overeating, overdrinking, exposure to cold after eating, fatigue or bad water may induce gastric disturbances resembling those from food poisoning. Furthermore, some people are abnormally sensitive to certain foods and may react violently to them, even though the foods themselves are absolutely harmless. For such attacks it would probably be better not to use the term "poisoning" at all. Technically, food poisoning is restricted to illnesses caused by naturally poisonous plant or animal matter, by accidental inclusion of some metallic poison in foods and by chance contamination with toxin-forming bacteria or other microscopic forms of life.

As an example of foods that are naturally poisonous it is scarcely necessary to remind you of the toadstool and similar varieties of toxic fungi. The danger of poisoning from this source is easily avoided by making certain that fungi are edible before using them. This can not be done by any magic trick, such as dropping a silver coin in the cooking receptacle. The best plan is for the private individual to learn how to identify one or two harmless species of mushrooms and to confine himself to those. Professional gatherers may obtain valuable information on the subject by consulting some authoritative classification

such as that offered by Krieger in the *National Geographic Magazine* of May, 1920.

Another curious example of naturally poisonous foods is provided by the common sea mussel in certain parts of the world. In recent years this cause of food poisoning has assumed great importance on the Pacific Coast, from Monterey in California far into Alaska. During the summer months these shellfish develop a poison which is, as far as we know, the most active toxin on record. As a means of preventing food poisoning from this source the State Department of Public Health has lately established an annual quarantine on mussels from early June until late September. Despite this safeguard individuals still insist on gathering mussels and eating them at home, occasionally causing death and often with less serious results. To be safe one should avoid these shellfish during the summer months, or if that is impossible, care should be taken to neutralize any poison that may be present. This may be done quite easily, investigation shows, by cooking the shellfish for twenty or thirty minutes in boiling water containing a quarter of an ounce of ordinary cooking soda for each quart. Numerous tests indicate that this procedure destroys about 80 or 90 per cent. of the poison and thus renders the mussels safe for consumption.

However, cases of food poisoning arising from these inherently toxic substances are in the minority. The primary causes of food poisoning are a number of varieties of microscopic plants and animals that get into the food while it is being prepared for use. Of course, there are also many actual disease organisms that contaminate food and enter the body through the mouth. Among the diseases that may be acquired in this way are trichinosis, dysentery, typhoid fever, septic sore throat, etc. These are not strictly food poisonings but are food-borne infections. In passing, however, it should be mentioned that trichinosis is entirely too prevalent in the United States at the present time. People should remember that this dangerous disease almost invariably comes from improperly preserved sausages, especially salami, or from insufficiently cooked pork products. Commercial sausage manufacturers may eliminate trichinosis by holding all pork for twenty days or longer at a temperature of 5° Fahrenheit. If this can not be done the ground meat should be mixed thoroughly with salt and after stuffing in the sausage casing should be held in a dry oven for not less than twenty days at a temperature not higher than 45° Fahrenheit. In making sausages at home these procedures are not practical, and it is therefore advisable to avoid the preparation of sausages which are eaten without cooking. *In the use of fresh pork safety may be assured by boiling or roasting it until the flesh is of a white, opaque color.* Care should be taken also not to give raw pork to domestic animals or to allow rats to reach it, as the disease may be spread in this way if the meat contains trichina (worms).

Typical food poisoning of a bacterial nature, however, is more predominantly gastrointestinal in its symptoms than the diseases I have just mentioned and usually develops within a few hours after eating contaminated food. While present-day knowledge of all the forms of microscopic life involved is far from complete, there are a few facts which can be presented. Hundreds and even thousands of cases of such poisoning undoubtedly occur without receiving a thorough scientific examination. Usually it is only when a large number of people are affected simultaneously, following a dinner, luncheon or picnic, that an investigation is made. Many such investigations by modern scientific pro-

cedure have revealed that a common form of organism resembles the typhoid fever bacillus in many ways and is therefore called the paratyphoid bacillus. It is not always possible to discover how this bacillus gets in the food, but in some cases it has been found that contaminated meat products came from animals infected with paratyphoid bacilli. In other cases the meat was contaminated after being slaughtered. In some countries where emergency slaughtering of beef animals is practiced, paratyphoid or Salmonella contamination from sick calves and cows is more prevalent than in the United States. Here it seems probable that contamination is more likely to take place during the handling of a foodstuff. This contamination may occur through a human carrier of paratyphoid infection or from infected animals such as house rats. It has occasionally been found that food poisoning has occurred as an aftermath of a rat extermination campaign where so-called "rat viruses" or living cultures of paratyphoid bacteria had been carelessly used. These methods of combatting rats are dangerous as well as ineffective and there is no justification for their employment. If efforts are made to keep the rat population at a low level, cleanliness and care, systematically practiced, will protect food supplies from contamination by rodent contact or droppings.

It should be remembered that food made dangerous by paratyphoid contamination is not readily detectable. It is not necessarily altered in appearance, smell or taste. The way to avoid it is by eliminating all opportunity for contamination. Thorough cooking and storage under refrigeration diminish the hazards of food poisoning. The eating of raw meat products involves a constant risk of poisoning. If animals to be slaughtered are given a careful inspection by trained men, and if meat from them is thoroughly cooked, the hazard of food poisoning is not very great.

Meat products are not the only media acceptable to microscopic organisms capable of causing food poisoning. A number of cases have been studied which apparently were caused by a toxin elaborated by the Staphylococcus, an organism vaguely resembling a Lilliputian bunch of grapes. The truth of this was checked by a volunteer group of scientific workers who swallowed small amounts of fluid in which staphylococci had been growing. The fluid was found to be a highly irritating metabolic poison. In about two thirds of the cases reported, this type of food poisoning has resulted from eating improperly refrigerated pastry, especially pastries containing cream or custard filling. Public health workers have found that this form of poisoning can be prevented by thoroughly cooking pastry filler and then promptly cooling it under refrigeration. Also, all utensils, such as filling bags and guns, must be sterilized daily and kept clean at all times. The production and distribution of cream pies or cakes during the warm summer months should be restricted to bakeries properly equipped with refrigerated storage or display cases.

Last but not least of the causes of food poisoning is the *Bacillus botulinus*. It is probably the most dangerous of all, involving a poison second in virulence only to the mussel poison previously mentioned. Fortunately, botulism is also more readily prevented than other types of food poisoning. It grows only in sealed containers or in food masses from which oxygen is excluded and this growth may be prevented by the application of sufficient heat. During the past 150 years the deaths of about 500 people have been traced directly to botulism. At one time it offered a serious threat to the canning industry of the

United States. Through extensive experimentation over the course of many years methods have been evolved to eliminate botulism and as a result not a single case of botulism has been traced to a commercially canned food for the past ten years. There have been some fifty cases of botulism, but in each case the source was an improperly prepared home-canned food.

Because of the fact that the state of California is one of the important canning centers of the world, the responsibility for the campaign against botulism has largely devolved upon the University of California. Members of its staff have found that the Bacillus botulinus is to be found everywhere in the soil. Thorough washing of fruit and vegetable products minimizes the chances of contamination but does not eliminate them. Certainty of freedom from botulism can be obtained only by cooking susceptible preserved products at very high temperatures. These temperatures must be above the boiling point, for the spores of botulinus have been known to withstand six hours of boiling. In commercial canneries this problem has been met by pressure cookers employing live steam, and by scientific tests a correct processing time has been determined for each important food. There are certain rules that every housewife should observe in order to avoid botulism. All home-canned, non-acid foods should be thoroughly boiled just before eating. This will destroy any poison present. Canned products should always be opened by an adult familiar with their normal appearance and odor. If there is the least trace of off-standard condition the product should be ruthlessly destroyed and never fed to animals or fowls. If there is no pressure cooker available in the home preserving of non-acid foods, it is safer to substitute drying, salting or pickling for canning.

A FREAK OR EVOLUTION?

By Dr. CHARLES T. BERRY
DEPARTMENT OF GEOLOGY, THE JOHNS HOPKINS UNIVERSITY

By what criterion do we distinguish between a freak and evolution? This is a puzzling question and one which is raised in connection with the conditions of the two animals I will tell you about in this paper. Nature tries a certain line of development, and if it does not prove to be efficient in the surroundings where it is placed, this line is either changed or discontinued; and in its place nature installs another variety. Do we term this unsuccessful line a freak or evolution? If we should find one specimen we should probably call it a freak, but if we have the entire line made up of what individually we might call freaks we would term it evidence of evolution. Likewise if we separated one of the links out of this long chain of evolution and placed it near one of the end-members of the chain we would be tempted to call this individual link a freak, whereas in reality it is just a step, in the line of evolution, out of order. This is the question brought out by the abnormalities in the two following cases which I want to describe. Are these turtles freaks or steps in evolution?

During my wanderings around Maryland in connection with some geological work I was doing three summers ago, I stopped to rest on the bank of a small stream in Calvert County. Being interested in all things pertaining to natural science I started to look around while I was eating my meager lunch. About fifteen feet from the bank of the stream I spied the empty shell of a turtle with a number of the outer epidermal scutes detached from the bone. I examined the remains more carefully only to discover that there seemed to be an extra plate on the turtle's back. I at once carefully gathered up all the remains I could find and packed them away, to take back with all my fossils to the laboratory. Once back in the laboratory, and my material unpacked, I looked at this turtle better and sure enough, there was an extra plate on its back. I put this specimen aside, since my geological work was occupying all my time, and did not think of it until I came upon another turtle shell some ten months later in Howard County, Maryland.

This shell also had an extra plate on it, but it was not the same one. However, I was not so fortunate with this specimen, for all the epidermal shields were fastened very tightly to the bone. These two finds aroused my curiosity very much, and from that time on I have been examining every turtle I have seen. Over a period of several years this amounts to quite a number. On none of the other turtles have I found any evidence of an extra plate. These two finds of mine are apparently just a coincidence.

This is the question. Is the presence of these extra plates a step in evolution or does it represent just freaks? Whichever is the case, they are of interest to the naturalist.

Both of these specimens belong to the same species—*Cistudo carolina* Linné. or the common box tortoise which is often seen in and around gardens and in the thinly wooded regions where there is sufficient moisture. This turtle lives to a very old age—the exact length is unknown—for they have been kept in captivity only about fifteen years. They wander about and do not dig holes in

the ground except in the winter time, and then they are liable to bury themselves to a depth of two feet or more. *Cistudo carolina* has a range from New England southward to Georgia and westward to the Mississippi River.

This common box turtle has been called by several different names, among which are *Testudo carolina* and *Didicla carolina*. These are still used by some authors; however the term *Cistudo carolina* is in good usage to-day and I will follow the current practice.

The first specimen (Fig. 1) which came from Calvert County had apparently been lying exposed all winter, for the scute plates had become detached from the bone, permitting me to observe the epidermal shields separated from the bone. This specimen has an extra scute plate situated on the left of its third vertebral plate, and partly intercalated between the second and third costal plates. The illustration is taken of the naked carapace with all the scutes removed so as to show how deeply the actual bone is grooved at the contact of the individual scutes. This extra triangular plate, which is very well marked off, is a little more than twice as long as it is wide. This scute plate shows all the usual growth markings and appears to be a unit in itself similar to all the normal scute plates.

There is, however, a slight irregularity in the color pattern on the right side of the third vertebral scute; but not enough to justify drawing any conclusion as to whether a similar plate might have been formed there or not. I examined the surface of the bone very carefully and there is no evidence that any extra plate might originate on the right side. I traced out the suture between the bony plates and could observe no irregularities due to the presence of the extra scute plate.

This Calvert County specimen, a male, is: 4 13/16 inches long; 3 7/8 inches wide; 2 1/8 inches high.

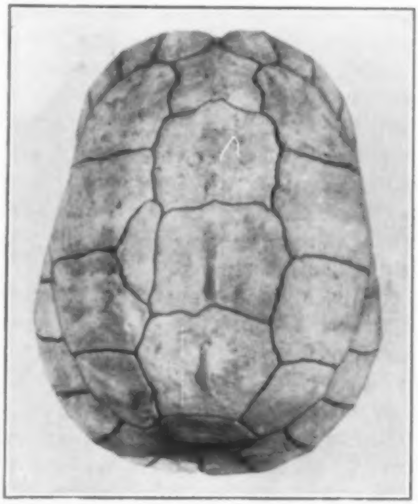


FIG. 1. CARAPACE OF COMMON BOX TURTLE MINUS SCUTE PLATES.

These measurements are within the usual ones for this type of *Cistudo*.

The second specimen (Fig. 2), which I found near Ellicott City, Howard County, is also of interest, due to the fact that there are two extra costal scute plates present. In this specimen the scute plates are strongly attached to the bony plates, thus preventing me from examining the outer surface of the bony plates.

Both of the fourth costal plates are divided into two plates, thus making five

FIG. 2. POSTERIOR END OF CARAPACE OF COMMON BOX TURTLE SHOWING EXTRA PLATES (x,y).

costal plates on each side instead of four. The division of the left plate is exactly like that of the right plate. This division of the costal plate does not affect the usual arrangement of the marginal plates. Since the epidermal shields are still fastened to the bone I am unable to see if the bone has a deep groove at the junction of the abnormal scute plates as can be observed on the other specimen. From all observation the arrangement of the bony plates is not affected by the irregularities of the scute plates.

By studying the growth lines on the fourth and fifth costal and the fourth vertebral scute plates it is evident that the division of the fourth costal plate took place at a very early time in the development of the animal, because traces of the pointed lobe of the fourth vertebral scute plate which is partly inserted between the fourth and fifth costal scute plate can be traced by means of the growth lines until nearly the original vertebral scute plate is reached.

This Howard County specimen, a male, is: 4 5/8 inches long; 3 13/16 inches wide; 2 9/16 inches high.

In searching through the literature one finds very little mention made of abnormalities in the number and character of the scute plates of turtles. The following case is one which I thought would bear mentioning:

G. H. Parker[1] cites two cases of abnormalities in the scutes and bony plates of the sculptured tortoise (*Chelopus insculptus* Le C.). One specimen has the appearance of having been deformed, so that the outline of the shell appears to be twisted from left to right. On this specimen both the scute and bony plates are irregular. The other specimen which Parker says probably came from Maryland is regular in outline, but there is one less marginal scute plate on both sides of the posterior portion of the carapace. This can be interpreted, the author thinks, as due to the shortening of the carapace. This fact he illustrates by measurements taken from a number of tortoises of the same species.

Now to mention conditions as found in a few fossil turtles. Within the last month I have examined the plaston of several fossil turtles of Miocene age. There are several instances where extra plates are present, showing that the abnormality of extra plates is not confined to the recent animals.

Just what is the cause of the irregularities that present themselves in those cases which I have mentioned? The scute plates are derived from the ectoderm, while the bony plates come from the mesoderm. This course is decided upon in the egg long before the turtle is hatched. The evidence of growth is present on the scute plates by numerous fine concentric lines and the age of a turtle can be determined similarly to that of a tree. One of the explanations which presents itself for the extra plates is that the shell of the turtle has been exposed to some accident. The other explanation is that some irregularity took place in the development of the turtle before it was hatched. I will dispose of the former point first.

There is always the chance that the shell of a turtle might be injured by some accident, such as a rolling stone, being stepped upon by cattle or being hit by some vehicle like a lawn mower. I have seen cases where a large portion of the margin of the carapace was missing from an injury of this kind. The bony portion was slowly being replaced to its original form but leaving a pronounced scar. In other cases I have observed shells of turtles which have been injured high up on the carapace. In this case the scar ran across the growth

[1] G. H. Parker, "Correlated Abnormalities in the Scutes and Bony Plates of the Carapace of the Sculptured Tortoise," *Am. Naturalist*, 35: 17–24, 1901.

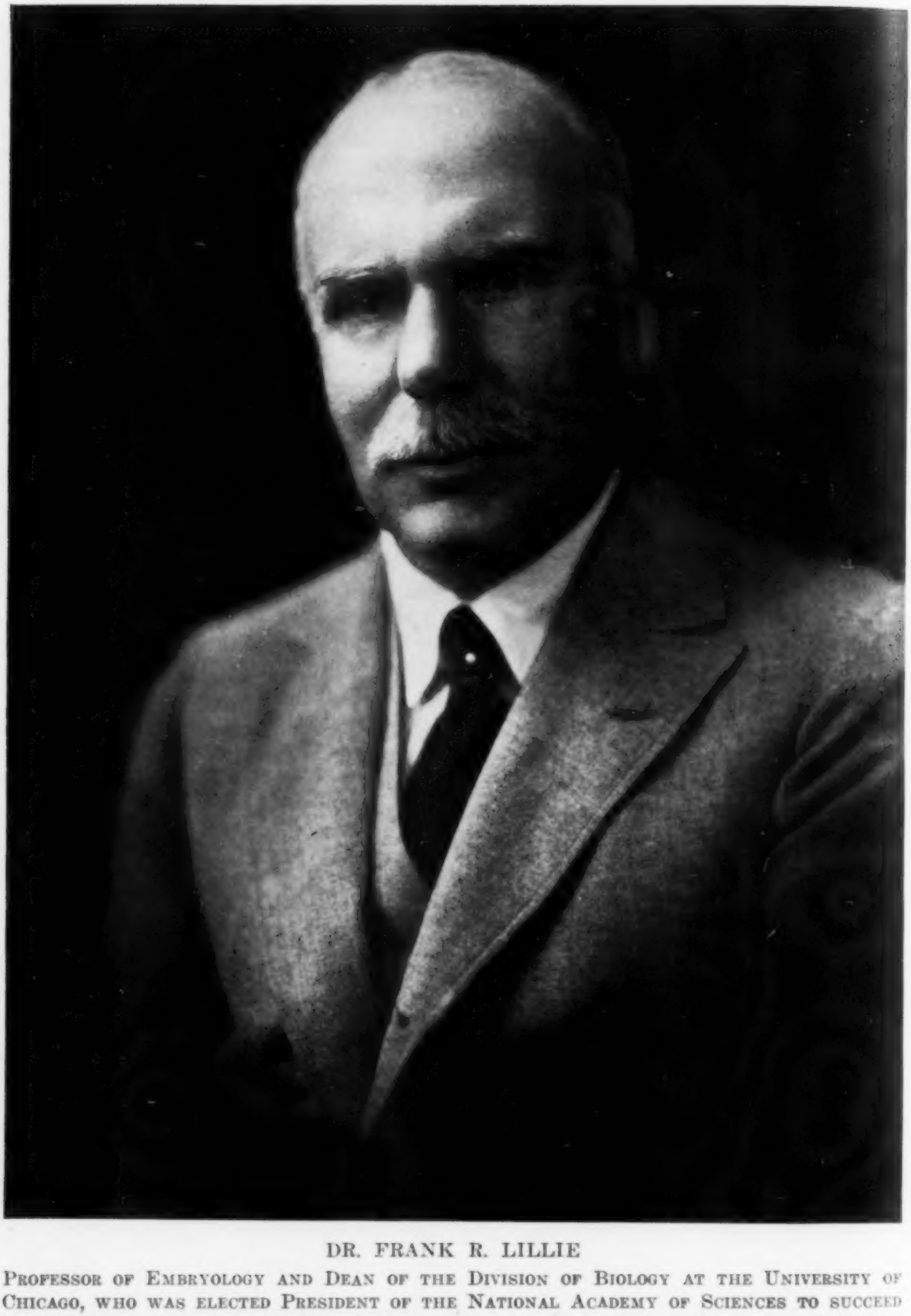
lines of the scute plates. In none of these cases was there evidence of the formation of new and differently shaped scute plates.

In both cases of *Cistudo carolina* there is no evidence at all of the animal's having been hurt sometime during its life. The growth lines of the odd plates are continuous from the first concentric lines to their last line. Where a sinus is found in the latter lines, this indentation can be traced backward until it disappears in the outline of the young scute plate. In these two cases the evidence of the extra plates can be traced to a very early stage in the development of the scutes. There are no breaks in the concentric arrangement of the growth lines.

This leaves the other question as the answer to the extra scute plates—that some irregularity took place in the development of the turtle before it was hatched. Just what this irregularity was is hard to say. It, however, only affected the growth of the ectoderm—that I am sure of in the specimen from Calvert County. Whether or not the mesoderm was affected as well as the ectoderm in the development of the specimen from Howard County, I can not say, but I feel sure that it was not.

Just what was the factor which brought about a change in the development of the ectoderm so that in some instances there appears a greater number of scute plates than is customary? If this difference only occurred in the development of a single egg we would call it a freak in the line of turtle history. But if the turtle continues to show more cases in which it grows additional plates we can term it evolution. Which is the truth in this case, time alone can tell. If it is evolution, time has taken thousands of years to prove it, for we have turtles in the geologic records from Upper Triassic to the recent. Most of these early turtles were much larger than the present-day ones, but the arrangement of their scute and bony plates is the same as that of their living descendants; with those exceptions where we find extra plates.

It is always interesting to speculate when dealing with evolution, but one should not let his mind wander from the plain facts too far or else he will reach an erroneous explanation. Thus I will leave the question open for others to decide for themselves—if they so wish—as to whether these two cases I have described are just freaks or steps in a line of evolution.



DR. FRANK R. LILLIE

PROFESSOR OF EMBRYOLOGY AND DEAN OF THE DIVISION OF BIOLOGY AT THE UNIVERSITY OF CHICAGO, WHO WAS ELECTED PRESIDENT OF THE NATIONAL ACADEMY OF SCIENCES TO SUCCEED DR. W. W. CAMPBELL, OF THE LICK OBSERVATORY. DR. LILLIE WAS ALSO ELECTED CHAIRMAN OF THE NATIONAL RESEARCH COUNCIL.

THE PROGRESS OF SCIENCE

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences was created by a special Act of Congress, approved by Abraham Lincoln on March 3, 1863. It was organized for two purposes—to encourage the development of science by honoring men who have contributed to knowledge by original research work, and to advise the Government on problems in science. As stated in the Charter "the academy shall, whenever called upon by any Department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expenses of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose; but the academy shall receive no compensation whatever for any services to the Government of the United States." The stipulation regarding compensation was wisely inserted to free the academy from any pressure which might be exerted on a paid agent and from criticisms arising therefrom. The organization meeting of the academy was held on April 22, 1863, and the first annual meeting on January 4 to 9, 1864. At this meeting 16 scientific papers were presented; in addition six different committees submitted reports on subjects on which several government departments had requested information and advice. These special committee reports were printed in the annual report of the academy for 1863 and cover 102 pages of the 118 pages of the report.

The seventy-second annual meeting of the academy was held on April 22, 23 and 24 at the academy building in Washington, D. C., with 113 academy members and one foreign associate in attendance. The scientific sessions were well attended and the scientific papers aroused interest and discussion. The distribution of the papers among the different fields of science was the following: Mathematics, 3; astronomy, 5; physics, 14; engineering, 1; chemistry, 3; geology, 1; geodesy, 1; botany, 6; zoology, 5; physiology, 3; pathology, 4; anthropology, 4; psychology, 3; biographical memoirs, 3. Academy members presented 37 papers; 18 papers were given by scientists introduced by academy members; and one paper was read by invitation. As a rule papers before the academy contain first announcements of the results of scientific research work. Summary statements of the scientific work of an organization or group are not customary; there are few invited papers; and rarely is a symposium held to consider a special problem on which information has been requested by the government. This attitude of the academy toward its scientific program has been adhered to since its first meeting and is reflected in the qualifications expected of a candidate for election; first and foremost he shall have contributed by original research work to the advancement of knowledge in his own field.

The Monday evening public lecture was given by Dr. Frank B. Jewett, vice-president of the American Telephone and Telegraph Company, on "Electrical Communications, Past, Present, and Future." Approximately 400 people were present at this extremely interesting address. At the scientific sessions the average attendance was approximately 500, both morning and afternoon.

On Tuesday afternoon academy members were invited by J. Edgar Hoover, director of investigation, to visit and inspect the Division of Identification of the Bureau of Investigation of the Department of Justice. The 50 or more members and guests who accepted

DR. DUNHAM JACKSON
PROFESSOR OF MATHEMATICS,
UNIVERSITY OF MINNESOTA.

DR. JEROME C. HUNSAKER
PROFESSOR OF AERODYNAMICS,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

DR. JOHN H. VAN VLECK
PROFESSOR OF PHYSICS,
UNIVERSITY OF MINNESOTA.

DR. HARVEY FLETCHER
ACOUSTICAL RESEARCH DIRECTOR,
BELL TELEPHONE LABORATORIES.

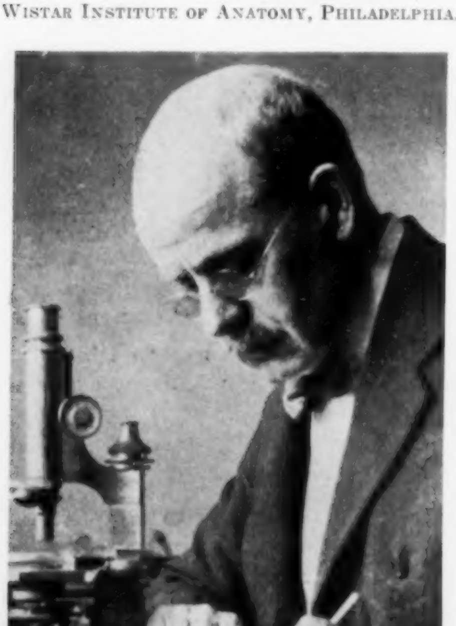
DR. HAROLD C. UREY
PROFESSOR OF CHEMISTRY,
COLUMBIA UNIVERSITY

DR. NORMAN L. BOWEN
PETROLOGIST, GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON.

DR. ROSS AIKEN GORTNER
PROFESSOR OF BIOCHEMISTRY,
UNIVERSITY OF MINNESOTA.

DR. CHESTER R. LONGWELL
PROFESSOR OF GEOLOGY,
YALE UNIVERSITY.

DR. GEORGE ELLETT COGHILL
PROFESSOR OF COMPARATIVE ANATOMY, WISTAR INSTITUTE OF ANATOMY, PHILADELPHIA.



DR. CHARLES M. CHILD
PROFESSOR OF ZOOLOGY, UNIVERSITY OF CHICAGO.

the invitation were shown the methods employed in the identification of criminals by means of finger prints and other records. The exhibition was most interesting and gave members an insight into the functions and efficiency of this arm of the government.

At the annual dinner on Tuesday evening President Campbell delivered, at the request of the local committee and of the council, a brief address on the functions of the academy, as stated in its Congressional Charter, and of the significance of the contributions of science to human welfare. His address concluded with the significant sentence:

> I think we are all in accord with the thesis that the vast body of known truth about our surroundings, as revealed by the ways and the means of the physical and biological sciences, is incomparably more wonderful and inspiring than the fiction of the most lively imagination and, being idealistic and non-materialistic in character, is of the imperishable treasures of the human race.

This was followed by the presentation of four medals: *the Agassiz Medal* to Haakon Hasberg Gran, of the University of Oslo; *the Henry Draper Medal* to John Stanley Plaskett, director of the Dominion Astrophysical Observatory; *the Daniel Giraud Elliot Medal and Honorarium of $200, for 1932*, to James Paul Chapin, of the American Museum of Natural History; *the Public Welfare Medal of the Marcellus Hartley Fund* to August Vollmer, member of the staff of the Department of Political Science, University of California.

At the business meeting held on Wednesday, April 24, the following officers were elected:

President: Frank R. Lillie, professor of embryology and dean of the Division of Biology at the University of Chicago, for a period of four years, commencing July 1, 1935.

Home Secretary: Fred. E. Wright, petrologist, Geophysical Laboratory, Carnegie Institution of Washington, reelected for a period of four years, commencing July 1, 1935.

New Members of the Council of the Academy: Ross G. Harrison, of Yale University, and Henry Norris Russell, of Princeton University, reelected for a term of three years, commencing July 1, 1935.

New Foreign Associates: John Scott Haldane, New College, Oxford University, Oxford, England, and Jules Bordet, Pasteur Institute, Brussels, Belgium.

Photographs of the fourteen new members accompany this article.

At the first general session of the academy on April 22, President Campbell read the following letter from the President of the United States:

As you and your eminent colleagues meet in the seventy-second annual assembly of the National Academy of Sciences, I bid you warm welcome to Washington, and express my cordial wish for the greater development and usefulness of the Academy.

The country has every reason to be proud of the record of its scientific men and engineers. In astronomy, medicine, physics, chemistry, geology, and other sciences, and in the progress of engineering in all its branches, the contributions of America have been and still are outstanding in a friendly world rivalry.

It is a matter for thankfulness that among the many sources of world distrust and jealousies, science preserves an ideal of purity, truthfulness and mutual good will toward all nations. Not only do cooperative international scientific projects flourish, but the publications of scientists are received at face value in all lands, even though they be politically at variance.

The National Academy's charter provides that the Academy shall be ready at all times to give advice when called upon by any branch of Government. This privilege has been availed of by Government on many occasions. One of the most notable was during the great war, when the National Research Council was established by the Academy at President Wilson's call to mobilize the scientific learning and ability of the country to aid in that great struggle.

I take this opportunity to thank the Academy for the advice and assistance it has given the administration during the past two years, particularly where problems pertaining to the scientific policies of the Government have arisen.

With renewed congratulations and best wishes, I remain

Very sincerely yours,

(Signed) FRANKLIN D. ROOSEVELT

DR. MERRITT L. FERNALD
PROFESSOR OF NATURAL HISTORY,
HARVARD UNIVERSITY.

DR. JAMES EWING
PROFESSOR OF ONCOLOGY,
CORNELL UNIVERSITY MEDICAL COLLEGE.

DR. WALTER S. HUNTER
PROFESSOR OF GENETIC PSYCHOLOGY,
CLARK UNIVERSITY.

DR. EARNEST A. HOOTON
PROFESSOR OF ANTHROPOLOGY,
HARVARD UNIVERSITY.

To this letter President Campbell replied as follows:

I have the great pleasure of acknowledging the receipt of your esteemed communication of to-day which extends to the members of the National Academy of Sciences a warm welcome to Washington for the holding of the Academy's Annual Meeting of 1935, and expresses your cordial wish for the greater development and usefulness of the Academy.

Your letter was read to the members of the Academy this afternoon at the opening of the first general assembly of this week's meeting, and I was requested and instructed to convey to you an expression of the Academy's deep appreciation of your thoughtful and courteous messages.

I am also requested to assure you that the members of the Academy are happy in their obligation and privilege of advising the Government of the United States on subjects within the domain of the physical and the biological sciences, whenever called upon by any branch or department of the Government for such service, under the wise provision of the Academy's Congressional Charter that "the Academy shall receive no compensation whatever for any services to the Government."

I have the honor to remain, Sir,
Yours respectfully,
(Signed) W. W. CAMPBELL, *President*

The present membership of the academy is 289 with a membership limit of 300; there are 44 foreign associates with a limit of 50.

The autumn meeting of the academy will be held this year on November 18, 19 and 20 at the University of Virginia at Charlottesville, Virginia. This meeting will be the first one of the academy to be held in the southeastern section of the United States.

F. E. WRIGHT,
Home Secretary

THE MINNEAPOLIS MEETING OF THE AMERICAN ASSOCIATION

THE ninety-sixth meeting of the American Association for the Advancement of Science is to be held in Minneapolis from June 24 to 29 inclusive. The University of Minnesota is host, as for the two previous Minneapolis meetings, and this year welcomes the Association to a new campus which is admirably

adapted for a successful meeting. Arrangements have been made for joint sessions and for exchange of privileges with the Minnesota State Medical Association which meets in the Minneapolis Municipal Auditorium from June 24 to 26. General headquarters are located in the Northrop Auditorium on the Minneapolis campus of the university. Hotel headquarters are located in the Hotel Nicollet.

In addition to the usual scientific papers in various fields the program of the meeting seeks to show what science has to offer towards the solution of present problems, especially in the Northwest. A strong group of speakers has been secured for the general sessions.

The Minneapolis meeting will open on Monday morning with registration at the Northrop Auditorium on the University of Minneapolis campus. The opening general session that evening is a joint meeting with the Minnesota State Medical Association, at which the address on "Diseases of the Blood" will be given by Dr. W. P. Murphy, of Boston, whose work on anemia brought him the Nobel prize in medicine. Tuesday evening the general session is devoted to the Maiben lecture. The speaker is Dr. Richard P. Strong, of Harvard University Medical School, and the topic, "The Importance of Ecology in Tropical Disease," will be illustrated with material from his recent expedition to Africa. Following this lecture an informal reception to visiting scientists will be tendered by President and Mrs. L. D. Coffman of the university. On Wednesday evening Dr. Isaiah Bowman, president-elect of the Johns Hopkins University, is to speak on "The Land of Your Possession." Thursday evening Dr. Wm. F. G. Swann, director of the Bartol Research Foundation, will address the general session on "The Nature of Cosmic Rays." The Friday evening general session will be addressed by Dr. Philip Fox, director of the Adler Planetarium and Astronomical Museum in Chicago, on the subject "The Scale of the Universe."

Of especial significance is the symposium on Conservation to be held Thursday morning. Through generous cooperation of the university several distinguished speakers have been secured to present to visiting scientists and to students of the University Summer School, then to be in session, the views of scientific workers on the problems of conservation and their solution.

The Minnesota State Medical Association will show a large series of demonstrations and exhibits to which members of the A. A. A. S. are admitted. Departments of the university have planned many exhibits and will keep open house throughout the week. The programs of sections and societies vary greatly but in many stress has been laid on symposia and joint sessions held in the forenoons, with field trips announced for the afternoons. Other field trips fill the entire day and a few extend over even longer periods, giving rich choice to visitors for contact with the unique features of the region. All persons are at least superficially familiar with the attractive environment of the Twin Cities, Minneapolis and St. Paul, and with the great vacation areas of lakes, streams and forest wilderness in the northern half of the state. These afford unrivalled opportunities for scientific study and vacationing. Those who seek information on the state will find it well described and illustrated in a recent number of the *National Geographic Magazine*.

The first Minneapolis meeting in August, 1883, was regarded as a daring venture into the Northwest, but the record of its proceedings forms an impressive annual volume in the early publications of the association. The record of the second meeting, held in December, 1910, showed an equally extensive and

varied scientific program. Details already reported give promise of similar variety and value in the program for this meeting. The work of secretaries of sections and affiliated societies has brought together material in diverse fields sure to interest members and visitors. The local committee, of which Professor D. E. Minnich is chairman and Professor D. G. Paterson, secretary, has done much to insure the success of the meetings, in which they have been aided by some forty associates from the university and the city of Minneapolis.

HENRY B. WARD,
Permanent Secretary

THE STRATOSPHERE BALLOON FLIGHT

THE 1935 stratosphere flight in *Explorer II*, like that of 1934 in *Explorer I*, will be made under the joint auspices of the National Geographic Society and the U. S. Army Air Corps. The ascent will be made from the Stratocamp, a cliff-encircled basin in the Black Hills, 12 miles southwest of Rapid City, South Dakota. The site of the Stratocamp was chosen both for the 1934 and 1935 flights because of the excellent facilities afforded for the project. The location toward the western edge of the Great Plains region provides a large expanse of unforested country to the southeast—the direction of drift—in which to land. The camp, protected on three sides by cliffs rising from 350 to 500 feet, and on the fourth side by hills equally high, furnishes an ideal place for the inflation of the huge balloon.

Balloon, gondola, and instruments will be assembled at the Stratocamp, ready for the flight, by June 1. The ascent will be made during the first weather favorable for stratosphere flying after that date. The weather conditions must be such as to promise freedom from clouds and excellent visibility over a large area to the east and south.

The purpose in sending this expedition into the stratosphere is to carry out measurements which can not be made through the blanket of the earth's atmosphere, which is equivalent to a layer of water thirty feet thick. A very large balloon is being used because in no other way can the instruments, which are necessarily heavy, be lifted to the desired height.

The investigations will include:

(1) Measurements of temperature and barometric pressure changes, from the earth to the highest point to be reached by the balloon; (2) Collection of samples of stratosphere air for analysis; (3) Cosmic ray studies, including the number and direction of the rays at various altitudes; (4) Spectrographic studies of sunlight and skylight, and the distribution of the ozone layer; (5) Sky brightness, sun brightness and earth brightness; (6) Wind direction and velocity studies; (7) Additional checks on measurements of altitude made by barometers; (8) Studies of the changes in the electrical conductivity in the air with increasing altitude; (9) Studies of high-frequency radio signals sent from the stratosphere and received on the ground; (10) Collection of spores in the stratosphere.

Captain Albert W. Stevens, U. S. Army Air Corps, will be in command of the flight and will have charge of the scientific program and instruments. Captain Orvil A. Anderson, U. S. Army Air Corps, will pilot the balloon. Captain Randolph P. Williams, U. S. Army Air Corps, will be in charge of ground operations and will stand by as alternate pilot.

The balloon to be used in the stratosphere flight, *Explorer II*, was designed and built by the Goodyear Zeppelin Corporation, in Akron, Ohio. It is larger than the *Explorer I*, which, at the time of its manufacture, was the largest balloon ever constructed. When fully inflated the *Explorer II* will be a sphere

Photograph by National Geographic Society—Army Air Corps Stratosphere Flight

PARTICIPANTS IN THE STRATOSPHERE FLIGHT

LEFT TO RIGHT, CAPTAIN ORVIL A. ANDERSON, PILOT; AND CAPTAIN ALBERT W. STEVENS IN COMMAND OF THE FLIGHT AND IN CHARGE OF ITS SCIENTIFIC ACTIVITIES; AND CAPTAIN RANDOLPH P. WILLIAMS IN CHARGE OF GROUND ARRANGEMENTS AND INFLATION OF THE BALLOON. THE THREE OFFICERS ARE STANDING IN FRONT OF THE 9-FOOT METAL BALL IN WHICH CAPTAIN ANDERSON AND CAPTAIN STEVENS WILL BE SEALED AIRTIGHT WHILE IN THE STRATOSPHERE. TO THE RIGHT OF CAPTAIN WILLIAMS IS AN INSTRUMENT WHICH WILL RECORD THE ELECTRICAL CONDUCTIVITY OF THE AIR. THE FLIGHT, UNDER THE AUSPICES OF THE NATIONAL GEOGRAPHIC SOCIETY AND THE U. S. ARMY AIR CORPS, WILL BE MADE FROM THE "STRATOCAMP" 12 MILES SOUTHWEST OF RAPID CITY, SOUTH DAKOTA, AS SOON AFTER JUNE 1 AS THE WEATHER PERMITS.

192 feet in diameter, 13 feet greater in diameter than *Explorer I*. The cubic capacity is 3,700,000 cubic feet, as against 3,000,000 cubic feet for *Explorer I*.

The bottom fabric of the bag (the portion in which tears occurred last summer) is made of the same weight as the main fabric of the balloon: three ounces to the square yard before the rubber was

applied; 5.3 ounces afterward. In *Explorer I* the bottom fabric was of two-ounce weight before it was rubberized. The top of the balloon bag is made of four-ounce cloth before the application of rubber.

The *Explorer II* will be inflated with helium; hydrogen was used last year. The primary reason for the change to the more expensive gas is to eliminate all possibility of explosion. Helium will not burn and remains inert when mixed with any proportion of air. Hydrogen, on the other hand, burns readily and forms an explosive mixture with air.

Since a given volume of helium will lift only 92 per cent. of the weight which can be lifted by the same volume of hydrogen it became necessary to give *Explorer II* a considerably greater volume than that of *Explorer I*, in order to reach the same ceiling.

When the balloon leaves the ground it will contain only about 300,000 cubic feet of helium, approximately eight per cent. of its capacity. Since the gas expands rapidly as it rises above the earth, it would be wasteful to start with more. The bag will become full and take on its spherical shape approximately 12 miles above the earth. Above this point the expanding gas will escape from the bottom of the bag through four appendixes or inverted chimneys of fabric.

The exact height to which the balloon will rise will depend upon a number of factors: the temperature and barometric pressures at time of take-off; the degree of extra expansion due to superheat caused by the shining of the sun on the bag; the total load of the balloon; the relationship between the weight of the ballast that can be discarded and that which must be retained for the down trip; and the amount of gas valved away in order to keep the balloon on the same level for certain periods. It can be estimated very roughly that the balloon should rise to an altitude above 70,000 feet or $13\frac{1}{4}$ miles. At this height the atmosphere will be only about 1/23 of the density of the atmosphere at sea-level. In other words, 22/23 of the total atmosphere will lie below the level of the balloon, and only 1/23 above it.

The balloon and its ropes weigh 6,350 pounds. The gondola, instruments, equipment, and men weigh 3,750 pounds. More than 8,000 pounds of lead-shot ballast will be carried. The entire weight of balloon, gondola, and load when it leaves the ground will be approximately nine tons. The balloonists will make their ascent into the stratosphere in an air-tight, metal ball which will be suspended beneath the balloon. This gondola or cabin is made of Dowmetal, a magnesium alloy lighter than aluminum. The metal shell is 3/16 of an inch thick, 9 feet in diameter and weighs 638 pounds. The gondola is provided with two elliptical man holes, slightly larger than those of 1934, and six observation portholes, covered with double thicknesses of glass. Midway between the man holes is a hinged arm, 14 feet long, which carries a propeller fan at the outer end. This fan, controlled from within the gondola and driven by a storage battery, will cause the gondola and balloon to turn slowly, thus pointing the instruments in any desired direction.

LYMAN J. BRIGGS

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